Chapter 13
Food Packaging Equipment

13.1 Introduction

13.1.1 General Aspects

Packaging of food consists of the operations shown in Fig. 13.1. These operations may be distinguished in package preparing operations, product preparing for filling operations, filling in packages, closing (sealing), control of filled packages, and preparation for storage and shipment. The equipment used in feeding the food into the filling unit depends on the nature and properties of the food. For liquids, pumps or gravity is used. For granulates or small pieces, transfer can be done pneumatically, by special pumps, gravity, or belts. Larger pieces are transferred to the packaging line by conveyors or trucks. Before being packaged, the product is stored shortly in feeding tanks or other containers. Depending on the filling technique, the tank may be open or closed. The product in closed tanks may be under pressure or in vacuum. When using trucks or conveyors, mounted on the ceiling, the short storage may be in intermediate bulk containers (Chap. 3), replacing the fixed short storage equipment. In all cases, the main aim of short storage is to have a product of constant properties. Therefore, if, e.g., a liquid food consists of mixed components, it is continuously agitated to secure homogeneity in consistency and temperature.

The packages are either ready to fill or partially ready to fill, or they are constructed in the food processing plant shortly before filling. Typical ready-to-fill packages are glass and metallic containers, woven textile package (e.g., jute bags), and some plastic containers. Packages, partially ready to fill, are mainly cartons, cardboard, and some special kinds of material such as “sleeve” packages, e.g., nets used for fruits and vegetables or sausages (“salami skin”). This type of packages is formed shortly before filling (e.g., laminated cartons used in packaging of frozen fish fillets or in aseptic packaging of liquids). Packages constructed before filling include the blown-mold, the thermoformed, and the tube-formed packages. The packages that come directly into contact with food are usually sterilized before

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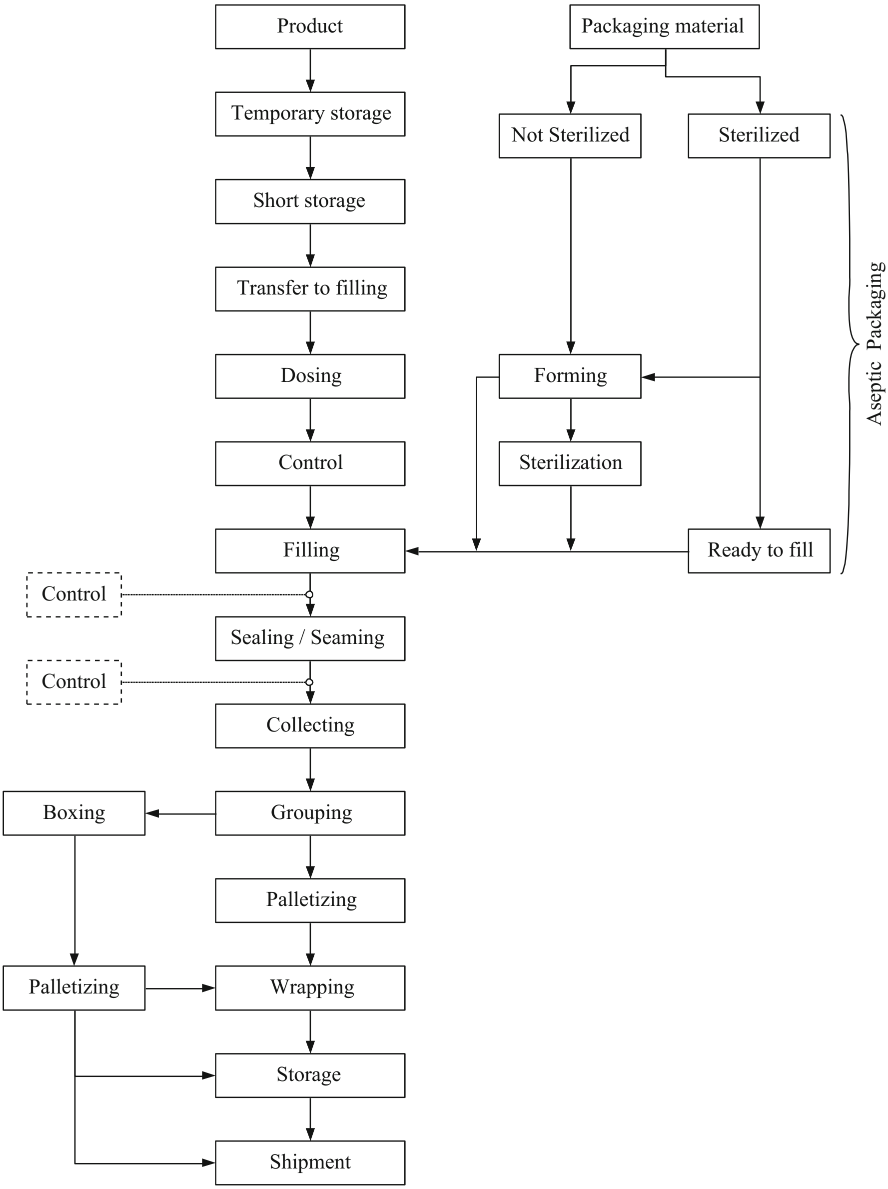


Fig. 13.1 Food packaging processes

filling. The method of sterilization depends on the packaging material, the product, and the way a container is constructed. The laminated cartons and the plastic films are usually sterilized chemically (e.g., hydrogen peroxide), while the glass and metallic containers are sterilized by hot air or steam.

"Filling" consists of transferring the product from the short storage to the dosing device and then to the filler and the placement and preparation of the package to receive the product (e.g., air evacuation of the container). Filling can be done under atmospheric conditions, in vacuum, in modified atmosphere, or aseptically. Filling is followed by closing of the containers. The plastic bags are heat-sealed or closed mechanically by clips. Cartons are heat-sealed or glued. Cardboard boxes are closed by adhesive plastic or paper tapes. Bags are stitched or closed by clips. Metal cans and bottles or jars are closed mechanically. The metal cans are seamed and the jars and bottles are closed by using several types of caps, e.g., caps that are not deformed during closing (screw and twist caps) and caps that are deformed (crimped aluminum and crown caps) (Robichon and Savina 1996). The cartons are either sealed by glue or they are closed mechanically (e.g., interconnection/locking, clips).

The filled and sealed packages are grouped and put on trays, in cardboard boxes, or directly on pallets. The grouped packages may be further wrapped by plastic film or kraft paper. In some cases, the packs are tightened together by tape or wire.

In packaging, the equipment can operate alone or as a monoblock, in which more than one operation take place, e.g., filling and sealing. In larger equipment, forming, filling, and sealing are partial operations in the same machine. Equipment standing alone is more flexible, but its capacity is not as high as that of the monoblock. Therefore, it is mainly used in smaller manufacturing units, in which a larger variety of products is often produced. However, this type of packaging line requires more space (Rice 1997). Monoblock equipment is used in vacuum, modified atmosphere, and aseptic packaging, since in these operations sealing must be done immediately after filling.

Packaging and packaging materials are discussed in the following books, among others: Robertson (1993), Luciano (1995), Brody and Morsh (1997), Soroka (1998), and Hanlon et al. (1999).

In addition to the general characteristics of the packaging machines and packaging material, in most cases of food packaging, the specific product characteristics are also very important, and packaging equipment requires special design to meet the specific product needs. Two examples of product categories, for which a significant number of special packaging equipment have been developed, are the confectionary packaging equipment (Hooper 1998) and the beverages (Giles 2000).

13.1.2 Packaging Characteristics

Even the best processing method is practically useless, if the right package or equipment is not available. The aseptic process, e.g., was familiar several years ago, but the widespread application of the method was achieved by the introduction of the aseptic form–fill–seal (FFS) packaging system. The same holds also for several products packed in modified atmosphere or for gas-containing foods and for the sterilization of food in plastic pouches.

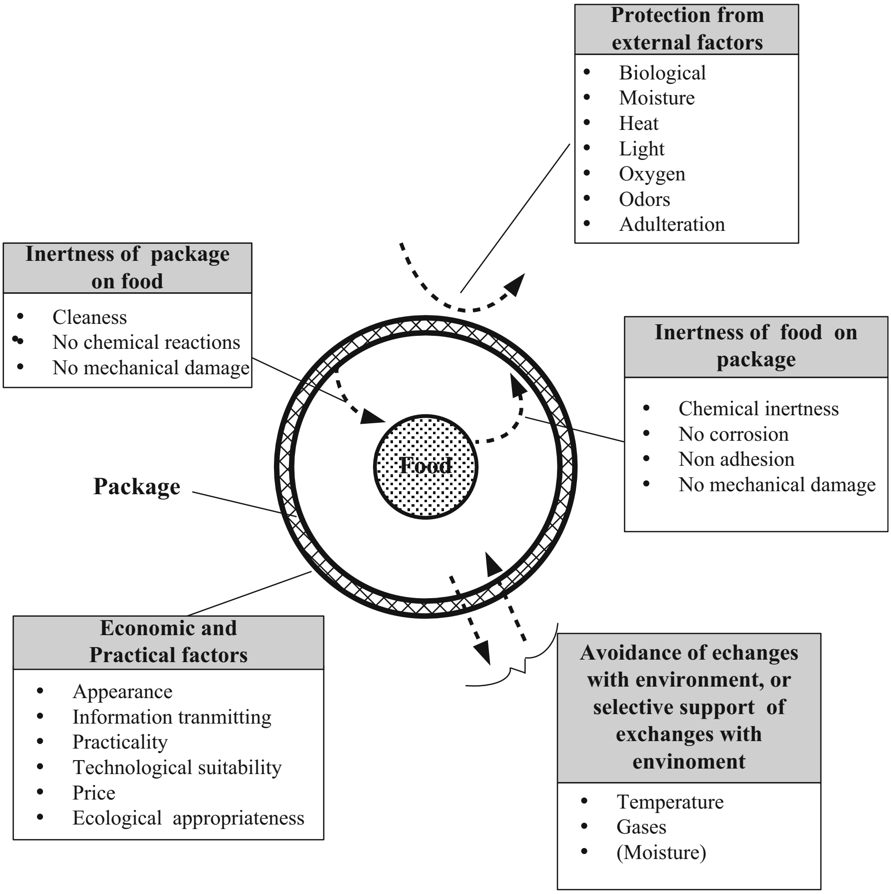


Fig. 13.2 Factors influencing the choice of food packages

The main objectives of food packaging are to meet the technical, safety, technological, economical, and ecological requirements. Figure 13.2 indicates the factors that must be taken into account when choosing food packages.

13.1.2.1 Technical Considerations

Food packaging must include the following considerations: (1) protection of the food from mechanical stress, (2) creation of conditions that protect the food from the physical environment, and (3) protection of food and the packaging material from chemical reactions.

Most foods are delicate products and, therefore, they need protection against stress conditions, which can occur during transportation (dynamic stress) or during storage (static stress). Furthermore, the packaging material must be strong enough to withstand mechanical stress due to processing methods (e.g., pressure differences during the sterilization process in an autoclave or in seaming of cans). Factors influencing the firmness of packages include the main material used (glass, metal, etc.), the quality of the material, the weight/quantity of the material (e.g., the thickness of plastic film), the design of the packaging material (e.g., laminated plastic film, corrugated kraft paper, etc.), and the design/construction of the package (e.g., the wall thickness of cans was reduced from 0.3 to 0.1 mm, after the introduction of the drawn iron process) (Robertson 1993).

The environmental conditions, such as temperature, humidity, light, oxygen, odors, and insects, influence strongly the food. In many cases, these factors are harmful or reduce the value of foods. High temperature is usually not desired during storage; it accelerates chemical and biological reactions, resulting in the faster degradation or spoilage of food. Humidity is often desired, if the proper low temperature is also applied, but there are products, such as the dried foods, which must be stored at low air humidity. Oxygen and light have negative effects on oils and fats and on some vitamins. They can also induce undesired chemical reactions. Odors influence the organoleptic properties of food, and insects, besides damaging the food, can be also a source of microbiological contamination.

The package must not be affected chemically by the food nor the food by the package. The composition of food (e.g., fat content) and several methods of food preservation (e.g., acidification, salting, heating) may cause problems to several metallic and plastic containers. Therefore, metal containers, e.g., must be provided with the proper varnish (enamel), and plastic packages must not be used, if they contain harmful plasticizers.

13.1.2.2 Safety Considerations

Food packaging must consider the following safety aspects: (1) protection of fresh products from deterioration, (2) protection of fresh and processed products from contamination, and (3) protection of food products from adulteration.

As a general rule, the food must be safe, meaning that fresh or preserved/processed food must be completely harmless to the consumer. Properly packaged fresh and preserved foods must be protected from quick degradation or contamination, e.g., due to dirt or environmental pollution. In most cases, packaging helps food to maintain its initial condition during storage, as far as possible. A special case is aseptic packaging, in which pasteurized or sterilized food retains the initial safety condition, due to proper packaging. Packaging guarantees also no adulteration after processing of food.

13.1.2.3 Technological Considerations

Technological considerations of food packaging include the following: (1) feasibility of the processes, (2) improving the quality of food, and (3) compatibility of packaging with existing processing equipment.

Several preservation methods (e.g., sterilization in cans) can be applied only if the food is packaged. Packaging is furthermore especially important, when it is part of a certain food preparation, as, e.g., in the case of tea bag and sausages. However, there are cases that packaging restricts the application of food processing methods. The aluminum, e.g., or other metallic packages are not suitable for microwave processing. Therefore, the thermal, mechanical, and other physical properties of food are very important in choosing the right package, in relation to the processing method applied.

Packaging may also contribute to the preservation or to the improvement of food. Several foods, such as various wines and cheeses, ripen better under controlled conditions provided by packages. Packaging can be also essential in protecting food from losing water (weight) and aroma substances. Packaging is also important in facilitating processes, such as the dosing, standardization, and control of food, and it enables the transportation, handling, and, in many cases, the storage of food products.

13.1.2.4 Economic Considerations

The following economic considerations are important in food packaging: (1) cost of packages, (2) attractiveness, (3) transmission of information, and (4) marketing.

Most foods are not luxury products and cannot afford the cost of very expensive packages. Therefore, one of the main criteria in choosing the right package is its price. The role of packaging is very important also in trade. Attractive packaging supports the sales and is one of the best advertisers of its contents. Attractive packaging, along with technical and technological characteristics of packages, facilitating food consumption, such as easy-to-open containers, one-way packages, packages combining several items (e.g., in ready meals), etc., is a factor contributing very much to the promotion of the food. Packaging is also very important in transmitting messages to the consumers. These can be, e.g., nutritional or technical messages; they can refer to the preparation or safeness of food, or they can be simply advertisement. The package can also facilitate marketing by giving information about the cost of food and the date and place it has been manufactured, as well as mentioning any guarantees given by the manufacturer.

13.1.2.5 Ecological Considerations

Ecological considerations of food packaging include recycling and disintegrations of packages.

Since consumers become more and more aware about environmental priorities, the packaging material must be either recyclable or it should be disintegrated. New methods in packaging technology extend the use of more ecological materials, such as paper and glass. In the case of glass, e.g., the increase of the container strength and the weight reduction improved their economic efficiency and competitiveness over other materials. When reused, glass bottles can be normally refilled up to 10–15 times.

13.1.3 Packages and Packaging Materials

The main packaging materials used for food are metal (tinplate, aluminum), glass, paper and its products, and plastics. In addition to the pure packaging materials, combined packaging materials, such as film laminates, plastic-coated glass, or metal, are used.

For more than 200 years, metal cans remain in the market. Their main advantage is their good retort ability and ability to protect their content in long-lasting periods, including strength. Developments such as the two-piece containers and the easy-to-open cans (peelable can lid) gave an upturn (boost) to the sales of cans. The two-piece metal containers dominate in the market of the smaller cans and about 70 % of small cans (mainly due to canned drinks) are foreseen with easy-to-open lids.

However, in the last years, permanent attempts take place, for developing retortable packages from other nonmetal materials. This effort is especially intensive in the sector of plastic containers. The development of retortable plastic materials and the consumers' preference to less long-life foods in connection to increased choice diversity and convenience boost the development of new products that favor the nonmetal containers. This consumption trend is also supported by developments in trade and logistics. The small flat plastic or even paper combined packages (boxes, trays, tubes) are easier placed in shelves of retail shops. They can be also used in packaging of frozen foods. The contribution of basic and technology research in this field is essential. Recently, even retortable carton packages and the incorporation of *nanomaterials* in packaging media have been developed and will probably open new fields. A recent example is the nanoclays that can improve the barrier properties of plastic films and other materials, making them less gas permeable and more antagonistic to metal containers also in this sector. Other nanomaterials incorporated in, e.g., plastic packages can be used as indicators of the freshness of products, as their color changes according to the storage conditions.

13.1.3.1 Metal

Metal is used to fabricate cans, tubes, aerosol containers, and larger containers, such as barrels and drums. It is also used in the fabrication of thin aluminum sheets, trays, and bottle and jar caps. For containers, the most frequently used form by far is the cylindrical. The metal cans are the most common type of metal container. There are two main types of metal can, the tinplate and the aluminum cans. Both are used in a very wide range of foods. The aluminum and the smaller tinplate containers are made of two pieces, while the larger tinplate and a part of the smaller cans are made of three pieces. Tinplate cans are made of 0.15–0.50-mm low-carbon mild steel that is coated 0.4 and 2.5 μm on the two sides. Thinner cans are constructed by the drawn and ironed method and the use of corrugated tinplate. The containers are enameled (4–12 μm), to avoid or reduce the interaction between food and the metal container. There are several types of internal enamel used, e.g., phenolic, epoxy phenolic, acrylic, oleoresinous, and vinyl. Most containers are enameled before being constructed, but if the tinplate is stressed significantly during the construction of the container, as in the case of the drawn and ironed can, the container is enameled after its construction (Robertson 1993; Schormueller 1966). In the construction of aluminum containers for food, the metal used must be at least 99.5 % pure. They do not need to be enameled externally, since they are corrosion resistant, due to the aluminum oxides covering the surface of the containers. Nevertheless, they are coated internally, in the absence of the protective oxide layer, when there is no oxygen (Schormueller 1966). The aluminum cans are lighter, but they require 35 % more material for achieving the same strength with the tinplate cans (Joslyn and Heid 1963).

The tubes are used in packaging, e.g., mayonnaise, mustard, and ketchup. They have the advantage of easy handling and preventing food from oxidation. In the food sector, the aerosol containers are used, e.g., for packaging of cream, mayonnaise, and syrups for ice cream. There are two main types, the type in which the propellant gas contacts directly the food and the type in which the food is in a flexible bag. The material of the container is usually tinplate, and the gas propellant is nitrous oxide, carbon dioxide, or nitrogen (Franz and Fuhrmann 1968; Robertson 1993).

Larger containers are used for packaging of liquids and products like fruit pulps. They are also used as protection of other packages, such as the aseptically filled bags. The thin aluminum films are used as gas barrier in laminated films and in packaging of products like chocolate. They are usually 0.005–0.200 mm thick. However, aluminum films, to be effective gas barriers, must be more than 0.015 mm thick, as at this thickness, the aluminum film does not have pores.

The aluminum food trays are made by compressing 0.02–0.25-mm-thick aluminum sheets into molds (Reichardt 1963). Usually, they are not coated. They are used in baking and in packaging of ready meals and frozen food. The metal caps for bottles are made of aluminum, while the larger lids are made of steel. In all cases, the caps and the lids are coated, or they have cork- or rubber-like additions. The twist caps are made of aluminum.

13.1.3.2 Glass

Glass is a very good material for food packaging, as it does not influence the food, it is not corroded, it can be sterilized, it is gas and moisture tight, it is transparent, and it can be cleaned up relatively easily. The disadvantages of glass are its brittleness, its weight, and its disability to withstand sharp temperature changes. Further weak points of glass containers are their reduced construction accuracy and their closure. The bottles are manufactured by the double-blow method and the wide-mouth jars by the press-blow method (Jasrzebski 1959). In both cases, the dimensions and the homogeneity of the glass package cannot be so accurate as the metal containers. The reduced dimensional accuracy of glass bottles, e.g., can cause problems when using high-speed bottling equipment. Furthermore, the inhomogeneity of the wall thickness increases the breaking possibility of the glass containers. The abrupt change of temperature must not exceed 40 °C.

With respect to the closure, leakage is possible, if it is not properly constructed, because it is made of other materials (e.g., metal). However, in the last years, the closures have been improved significantly. Besides, the still popular crown cap has proved to be a good airtight closure of bottles over many decades. Cork is still used in closing bottles of wine. In addition, aluminum twist caps are used, especially in connection with the one-way closures and other hermetic closures The caps and lids consist of an inside metallic coated shell (steel or aluminum) and an impermeable sealing material, which may be natural or synthetic rubber, polyvinyl chloride material, or other appropriate plastic (Downing 1996). There is a quite wide variety of closing systems, which are usually patented. Capping can be achieved, e.g., by screw-on, crimp-on, roll-on, and push-on closing equipment.

The external coating of glass containers with 0.2 % polyurethane-based plastic film and better design has increased the strength against impact forces by 50 % and reduced the weight of bottles by 40 %. It reduced also the attrition between bottles during conveying in the filling station.

13.1.3.3 Paper, Carton, and Cardboard

Paper is very widely used in food packaging, to wrap products and to create bags, cartons, cardboard, and their products, because of its relatively low price, the possibility to be used in combination with other materials (e.g., in laminates), its low weight, the diversification in many quality categories, the almost neutral behavior against food, and it being environmentally friendly. The disadvantages of paper are its low strength against mechanical stress, the low moisture resistance, the inability to be sealed, and that it is attacked by insects and microorganisms. According the treatment of the pulp, used in paper manufacturing, there are two main paper categories used for packaging, the fine sulfite paper and the coarse sulfate paper. The packaging paper may be further subdivided into: kraft and vegetable parchment paper, bleached paper, greaseproof paper, glassine paper, and tissue paper. Kraft and parchment paper belong to the sulfate paper category. The sulfite category, besides sulfite paper, includes the greaseproof, the glassine, and the tissue paper (Fellows 1990). All these types of paper are produced in several varieties.

In relation to packaging, the sulfite paper is used for small bags and pouches, for foil laminating and for making waxed papers. The kraft paper is used in wrapping and in the manufacturing of multi-ply papers, corrugated board, cardboard, and their products (bags, sacks, boxes, etc.). Kraft paper is a strong heavy duty paper, weighing 70–300 g/m^2. It can be water repellent and, with the exception of fresh fruits and vegetables and dry products (e.g., sugar, cereals), it is mostly used in wrapping as a secondary protective packaging of food. The vegetable parchment paper has a greater wet and oil strength than kraft paper. It weighs 12–75 g/m^2 and it has almost the tensile strength of the kraft paper. The sulfite paper weighs 35–300 g/m^2 and it is used for grocery bags and labels, since it gives very good printing results. The greaseproof paper, weighing 40–150 g/m^2, is used in packing baked and fatty products. It is fat resistant, but it loses this property if it is wetted. The surface of the glassine paper is smooth; it is fat resistant and about half as heavy and strong as the kraft paper. The tissue paper is light (20–50 g/m^2); its strength is low and it is used in wrapping fruits for protecting them from dust and dirt (Robertson 1993; Fellows 1990). Papers can also be waxed, if water resistance and sealability are required. Waxed papers are used in bread wrapping and for inner lining of cereal cartons. However, since wax sealing is not so strong and wax also tends to crack when the paper temperature is low, wax coating is often replaced by plastic coating. This is, e.g., the case in cartons that are used for frozen food.

In manufacturing paper bags, paperboard consisting of 3–6 plies of kraft paper weighing 65–114 g/m^2 each is used, which is strong against tension stress. In manufacturing cartons for food, a white board, made of bleached chemical pulp, which weighs at least 250 g/m^2, is used. Generally, the board is stiff and it creases without cracking. Cardboard is thicker and heavier than paperboard, and it consists of 2–5 plies of kraft paper; it is about 1.00–3.00 mm thick, weighing about 560–1800 g/m^2 (Robertson 1993). There are two main forms of cardboard, the solid and the corrugated. The solid cardboard is used in creating paper drums and boxes. The corrugated cardboard is used for wrapping and for making boxes. The board is coated with polyethylene or polyvinyl chloride, for achieving sealability. A simple corrugated board is a fluted kraft paper, which is used as a cushion against impact stresses. Nevertheless, the corrugated cardboard that is used for boxes is a multi-ply material, consisting of a combination of plain and corrugated kraft paper. The plain kraft paper usually weighs 205 g/m^2 and the corrugated 127 g/m^2 (Robertson 1993). The height and the number of flutes of the corrugated configuration determine the type of the cardboard (Table 13.1). If the height of the flutes is small and the number of flutes per meter is large, then the corrugated cardboard gives rigidity to the package. If the height of flutes is large and the number of flutes per meter is small, the packaging material is suitable for protecting the packed product against impact forces. For heavier materials, more layers of corrugated and plain paper are used. In these combinations, the configuration of plain to corrugated paper is constant, or it may vary. In the case that the configuration does not remain constant, three different types of corrugated–plain combinations may form together the whole packaging material. Carton may be now also used for retortable aseptically filled containers.

Table 13.1 Typical cardboard dimensions

Category	Kind of corrugation	Thickness or flute height of corrugated cardboard (mm)	Corrugations or flutes per m
Type A	Large corrugation	>4.5	110–116
Type B	Small corrugation	2.0–3.5	152–159
Type C	Medium corrugation	3.5–4.5	123–137
Type E	Microcorrugation	<2.0	294–313

Data from Souverain (1996) and Robertson (1993)

13.1.3.4 Plastics

Plastic materials are widely used in food packaging. Their applications cover different types of packages. They are used in bags, pouches, and containers, for wrapping, and as components of compound and laminated packaging media. Some reasons of the rapid expansion of plastics use in packaging are their relatively low price, their easy processing, the possibility to modify their properties, the good relation of weight to firmness, the possibility of thermal sealing, and the possibility to use them in combination with other packaging materials. Disadvantages of the plastics are their low resistance to high temperatures, restrictions in using for food due to substances added for enhancing their physical properties, and environmental pollution-related problems. Plastics can be classified according to their texture into flexible (e.g., film) and rigid (e.g., plastics used for containers). Another possibility is to classify them on the basis of the raw material used. In this case, they are distinguished into natural (e.g., rubber), and synthetic plastics (produced mainly by polymerization, concentration, and addition of chemical compounds of smaller molecular weight) (Reichardt 1963). The plastic properties can be influenced in many ways, such as change of the molecular size, the method of preparation, the addition of substances, and radiation.

Plastics can be used as they are or in a modification, but very often they are used in combination with other plastics or other materials, for enhancing their properties or for giving them new properties. The laminated plastics that are produced by co-extrusion are especially important. The plastics that are most common in food packaging are polyethylene (PE), polyvinylidene chloride (PVdC), polypropylene (PP), polyesters (PET), cellulose, and rubber hydrochloride (Miltz 1992; Hernandez 1997).

Polyethylene (PE) is one of the most common plastics. There are two basic forms, the high density (HDPE) and the low density (LDPE). Both types can be heat-sealed (sealing temperature: 121–170 °C) and are suitable for shrink wrapping. The HDPE has 95 % crystalline form and can be used up to 120 °C, while the LDPE has 60 % crystalline form and can be used in temperatures up to 90 °C. The PE is cheaper than the other plastic films and has relatively good mechanical properties. The lowest temperature at which PE can be used is −60 °C. The LDPE is the most elastic plastic material and as strong as PVC in impact stress, but it has a low tensile strength and it is very soft. Its moisture permeability is very low, but it has a relatively high gas permeability and its resistance to oils and odors is low. The HDPE is stronger but more brittle than the LDPE. It is used also in replacing multilayer paper bags especially in cases that the product must be protected from moisture. Generally, stiffness, tensile strength, and chemical resistance of PE increase with density, but gas and vapor transmission, elongation, low-temperature impact strength, and environmental crack resistance decrease when the PE density is increased (Reichardt 1963; Schormueller 1966; Brown 1992; Robertson 1993).

PVdC has low moisture, gas, fat, and alcohol permeability. It is a little less elastic than PE and it is an odor barrier. In packaging, it is much used because of its good stress crack resistance. PVdC shrinks at relatively low temperatures, but at 150–170 °C, it shrinks about 30 %. Due to its low moisture, gas, and odor permeability, it is widely used in wrapping many foods, or as gas and moisture barrier in compound packages. Its use is extended from frozen products to fresh and dried food. PVdC is also used in vacuum packaging and in coating other materials. It is heat-sealed with other materials or with itself and withstands hot filling and retorting (e.g., retorted foil pouches, trays, and plastic tubes). Often several new types of packages require the development of new packaging equipment. This is mainly developed in the laboratories and workshops of the companies delivering the related packaging materials. However, occasionally, they are also developed in laboratories or workshops of large food processing companies, which poses the new invention. PVdC, like PE, is used as moisture barrier and in sealing packages that are made of materials that cannot be heat-sealed. However, since PE is cheaper, it is mostly preferred in cases in which gas tightness is also required (Joslyn and Heid 1963; Schormueller 1966; Robertson 1993).

Polypropylene (PP) has about the same elasticity as PVdC. Its tensile strength is four times that of PE and it is very widely used in making rigid plastic packages but also as flexible packaging material. The low-density PP is one of the few plastic materials that combines economy with the toughness that is necessary to form double seam seals (Brown 1992). Its moisture and fat permeability is low, but it is permeable to many gases and air. It is heat-sealed, and fine tapes of this material are used in making woven bags. PP is also used in making caps and closures for bottles and thin-walled pots by the blow-mold method. PE becomes brittle at temperatures near the freezing point (Joslyn and Heid 1963; Schormueller 1966; Robertson 1993).

Polyesters (PET) have significant tensile strength in a wide range of temperatures (−60 to 150 °C). They have relatively low moisture, gas, and aroma permeability and chemical resistance. They are very often used for beverage containers, except milk (Brown 1992). They are used for bags which contain frozen products and are subsequently put in boiling water. PET is used for creating bottles by the blow-mold method and as external film in laminates with PE (Schormueller 1966; Domininghaus 1969; Robertson 1993).

Polyamide (PA) is a strong material and its tensile strength is three times that of PE and 1/3 that of PET, and it is ten times harder than PE. The PA, which is also known as “nylon,” has a low water permeability (40 times less than PET) and a low gas permeability (comparable to that of PET). It can be used at temperatures between −40 °C and above 100 °C (the melting point of nylon-6 is 215 °C). Therefore, it is used for boil-in bags or in cases in which the packed products will be thermally processed. They can be sealed by the high-frequency or the flash heat method (Reichardt 1963; Domininghaus 1969; Nehring and Krause 1969; Robertson 1993).

Polytetrafluorethylene (PTFE), known also as Teflon, is very heat resistant, has very low coefficient of friction, has nonadhesive properties, and is chemically inert. It can be used at temperatures up to 230 °C. However, since it is expensive, it is used only in connection with thermal-resistant coatings of containers that are reused and in cases when stickiness must be avoided. A common use in packaging technology is the PTFE coating of the heat sealing elements (Werner 1955; Robertson 1993).

Rubber hydrochloride has the tensile strength of PVC, the elasticity of PVdC, and almost the same shrink property. It can be used up to 90 °C, but it becomes brittle at low temperatures (Reichardt 1963; Schormueller 1966).

Two types of cellulose are used in packaging, cellulose acetate (CA) and regenerated cellulose (RC). The tensile strength of both types is three times that of PE and the hardness of CA is half of that of PA. The water permeability of both types is very high. However, cellulose, since it is cheap, environmentally friendly, very transparent, resistant to oil if not wetted, and can be used at temperatures between −50 and 100 °C, is often used in packaging food. The RC is used in packaging of dry and other non-moist materials. With lacquers making it waterproof or in connection with PE, it is also used in wrapping moist food. The CA is mainly used to protect fruits from dust and in “transparent windows” of carton packages (Jasrzebski 1959; Joslyn and Heid 1963; Schormueller 1966).

13.2 Preparation of Food Containers

13.2.1 Unscrambling

Ready-to-fill packages (bottles, jars, cans) usually come to the filling line from the container manufacturing plants, packed on pallets. They are subsequently arranged in the packaging line (e.g., a belt conveyor) orderly, e.g., by special de-palletizers. However, there are cases that the containers are disordered. This happens, e.g., when plastic bottles are emptied in hoppers for automatic feeding. In this case, the bottles are set in order by an unscrambler, aided by compressed air. There are several types of such units.

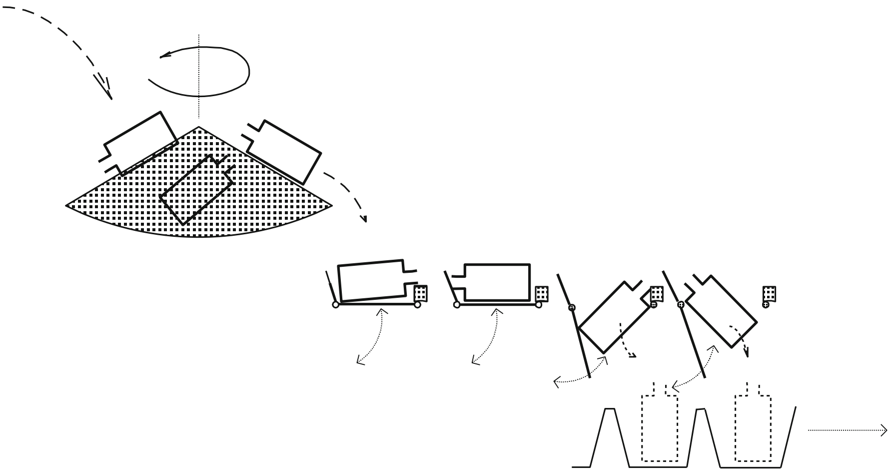


Fig. 13.3 Unscrambling bottles

In all cases, the containers are recirculated, until they come to the right position. Damaged bottles are automatically removed. In some systems, parallel belt elevators run in vertical funnels, taking the bottles from a hopper upward. On the upper part of the funnels, only bottles having the mouth up are conveyed to filling. There is equipment with more than 20 funnels. In another system, the bottles rotate in an open inclined drum, until they come to the right position. Unscramblers are also used in feeding caps to the bottle closing machine. The capacity of plastic bottle drum-type unscrambling equipment may exceed the 20,000 bottles/h. The capacity of the funnel-type unscrambler is higher. All types of equipment can unscramble plastic bottles of different dimensions. They require about 600 L of air/h at 6 bar of pressure and the installed power is about 10 kW. In the unscrambling of caps, the capacity is higher. An inclined drum-type unscrambler may have overall dimensions of $3.0 \times 2.0 \times 2.0$ m. The height of funnel-type unscramblers is 3.0–5.0 m. Figure 13.3 indicates basic operations of a bottle unscrambler.

13.2.2 Fabrication and Forming of Packages

The fabrication and forming of various kinds of food packages is described by Robertson (1993), Wilhoft (1995), Mallett (1996), Bureau and Multon (1996), and Paine (1996). In forming of containers, two main categories are distinguished, i.e., the erection of prefabricated containers (cartoning) and the film-based packages, formed shortly before filling. Often several new types of packages require also the development of new packaging equipment. This is developed in the laboratories and workshops of the companies delivering the related packaging materials, but occasionally also in installations of large food processing companies. Sometimes the companies that pose the innovation, reverse engineering on not owning the new innovation equipment manufacturers, that are able to realize the required new packaging machinery (Butte 1989).

13.2.2.1 Metal Containers

Only very large canning companies manufacture the metal containers themselves. In most other cases, the metal containers are manufactured in special factories which deliver them to the canning factory "just in time," or in the case of periodically operating canning factories, the containers are stored until the next processing period. If the finished products are not shipped out immediately, they are stored in the room that is emptied, as the containers are removed for filling. The basic construction of rigid containers (cans, bottles, drums, etc.) is not covered in this book. However, the construction of paper and plastic containers during the packaging operations, in the food processing plants, is discussed briefly here.

13.2.2.2 Cartons and Cardboard Packages

The erection of packages is mainly applied in connection to rectangular carton and cardboard containers. The cartons, which consist of laminated paperboard, 0.3–1 m thick (Paine 1996), are used in packaging of frozen and dried products. In many cases, they are also used as an additional package of paper or plastic bags. The cardboards are mainly made of corrugated kraft paper and used for packing grouped smaller containers.

The cardboard blanks, which come folded in packs, are placed in the packaging equipment magazines. Each folded cardboard blank is shaped to a box, after being picked up automatically by suckers from the magazine. A machine can have 2–4 suckers. Besides the sucker system, it is possible to use robots, which take the prefabricated packages from a separate pack or pallet and place them in interchangeable forming mold systems, in which the cardboard blanks are compressed by plungers. A machine may have more than 2 mold systems, which can be quickly replaced by others, if new sizes of packages must be formed. Packages can be top loaded (Fig. 13.4a), end loaded (Fig. 13.4b), or wrapped around the product (Fig. 13.4c) (Harrison and Croucher 1996; Behra and Guerin 1996). After erecting and filling the product, the packages are heat-sealed or sealed with adhesives (glued). In food packaging, the heat-sealed or glued cartons prevail, since they give moreprotection against microorganisms and adulteration than containers formed mechanically. In addition, gluing or sealing requires half as much time as mechanical locking (interconnecting) of the carton parts. However, when using glue for packages that will be filled with frozen products, the glue must be of quality suitable for low temperatures. The capacity of cartoning equipment is 1200–20,000 packages/h (Harrison and Croucher 1996). The power consumption is about 5 kW. The dimensions, including a conveyor 1.5 m long, may be 4.0 × 1.5 × 1.5 m and the weight 1.0–1.5 tons.

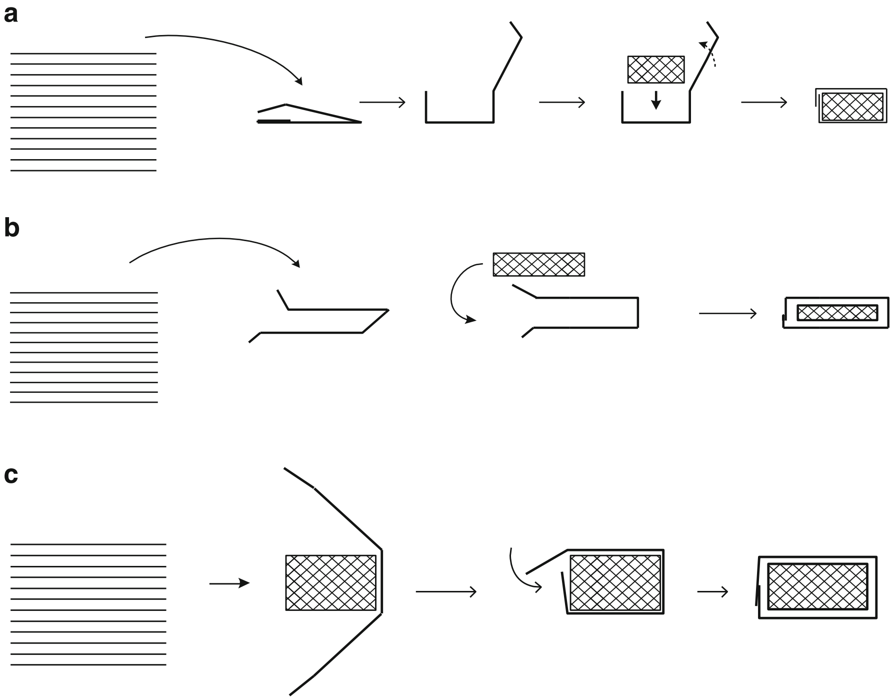


Fig. 13.4 Methods of forming cartons. (**a**, **b**, **c**) Packaging stages in different types of cartons

13.2.2.3 Film-Based Packages

In the construction of plastic packages, distinction is made between packages created by using plastic film and packages created by extruding plastic granulates. In using films, there are three main methods: (a) the tube method, which is used in creating bags and rectangular packages, (b) the pouch method, and (c) the thermoforming method, which is mainly used in creating cups.

Tube Packages

The tube-type package is widely used in packaging liquid foods and in the aseptic packaging. In almost all cases, laminated material is used. The tube material depends on the product and the method of packaging. Usually, it consists of polyethylene, aluminum, paper, and other 2–3 materials. Aluminum is used for gas sealing, polyethylene in direct contact with food and for heat sealing, and paper for giving rigidity. Aluminum film thicker than 9 μm is a perfect gas barrier (Church 1994).

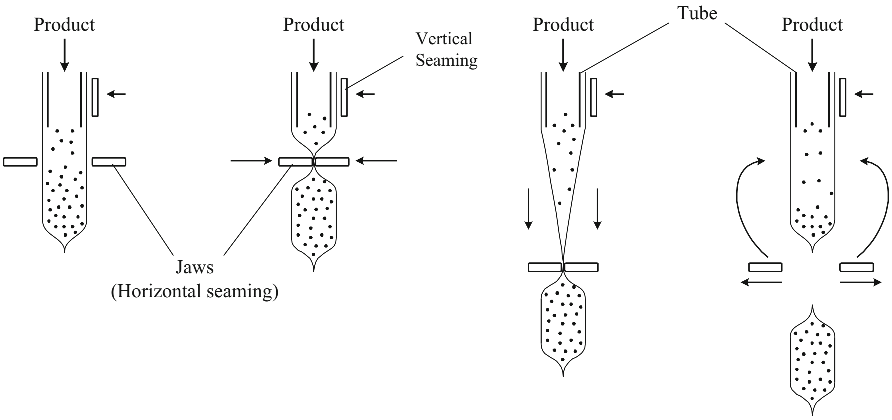


Fig. 13.5 Forming of tube packages (jaw-pull system)

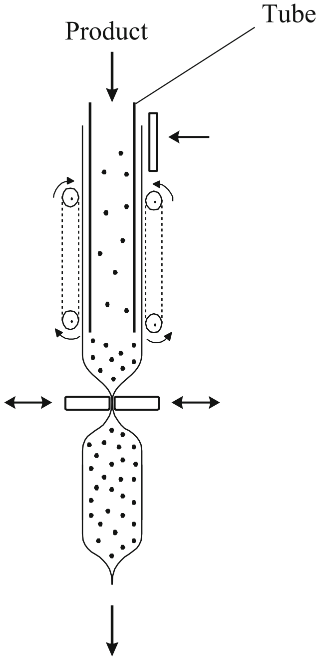
A significant part of equipment used in making tube packages is monoblock. Bags are formed by pulling the film out from a reel downstream. The film is wound around a metallic tube and both its ends are sealed vertically together, forming a plastic tube. There are two possibilities of sealing: the lap and the fin seal. The first is more stable, while in the second, the printed "messages" on the package surface look better, as the seam disturbs less. Horizontal jaws seal the plastic tube in exact distance, as it slips downstream along the metallic tube. Every second sealing, the filling of the bag follows, which is done through the metallic tube. There are two main variations in moving the plastic tube vertically. In the first variation, the film is pulled down, each time that the jaws seal the plastic tube downstream (Fig. 13.5). In the second variation, the movement of the plastic tube is done by roll belts (Fig. 13.6). In both cases, the filled and sealed bags are separated from the plastic tube by knives, incorporated in one of the two jaws (Fig. 13.7).

The tube system enables the creation of several types of packages (Fig. 13.8). It is possible, e.g., to create a rectangular package, if the lower part of the cross section of the tube is a tetrahedron (Fig. 13.8). The capacity of a tube-packaging machine depends on the type of the bag formed. For simple-form bags (Fig. 13.5), it is about 4000–6500 packages/h for packages of 200–1000 mL. For more complicated forms, such as flat-bottomed bags, the capacity is lower (about 2500 packages/h). In a variation, the tube and the pouch machine can produce two bags at the same time, doubling their capacity. The power consumption is 4–20 kW. They also need about 30 m^3 of compressed air/h at 6 bar of pressure. The overall dimensions, including a roll of film, are about $2.0 \times 1.5 \times 2.0$ m and the weight of such a machine is about 1.5 ton.

Pouch Packages

Bags are created by the pouch method, using film that comes from two reels and seamed on four sides, at capacities up to 8000 packages/h. The pouch equipment

Fig. 13.6 Forming of tube packages (belt-driven system)



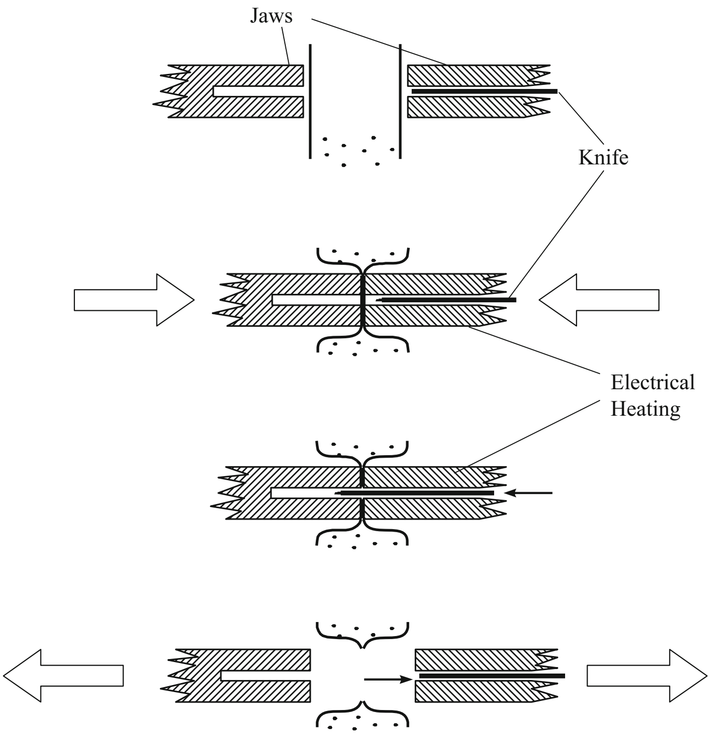


Fig. 13.7 Cutting of the bags from the tube bag

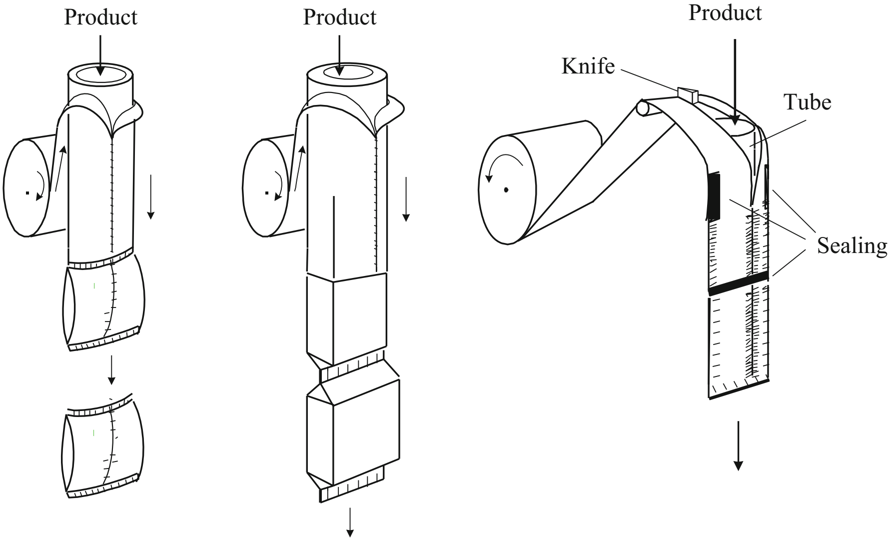


Fig. 13.8 Tube-formed packages

can be used for a wide range of products. Quite often, it is used for packaging powders and nuts. In the pouch method, there are two variations (Fig. 13.9). In the first variation (horizontal movement of pouches), the bags are formed by further sealing of a folded film, and the two vertical sides and the upper side of the pouch are sealed, after filling with the product (Fig. 13.9a). In the second variation (vertical movement of pouches), the pouches are created by sealing the films, rolled out of two reels (Fig. 13.9b). This system is similar to the tubular packaging system (Fig. 13.8). In both types, the films are sealed on three sides, while the fourth side is sealed after the pouch is filled with product through a tube. Both types have higher capacity than the tube equipment, but the capacity of the horizontal equipment is a little higher, e.g., 5000–12,000 packages/h (pouch size: 250–180 mL). The power requirement is 3–10 kW and the compressed air (6 bar) consumption is 8–15 m^3/min. The overall dimensions of the horizontal pouch equipment, including the roll, are 7.0 × 2.5 × 3.0 m and its weight is 1.5–2.0 tons. The dimensions of the vertical variation are similar to those of the tubular equipment.

Thermoformed Packages

Thermoformed cups or trays are used for packaging milk products such as yogurt and ice cream, juice, jam, dressings, ready meals, etc. They are formed as indicated in Fig. 13.10. Cups, e.g., are formed by pressing the laminated film that comes stretched over a mold (die) that has the shape of the package that will be created. The film comes from a roll and it can be either preheated, e.g., in an infrared

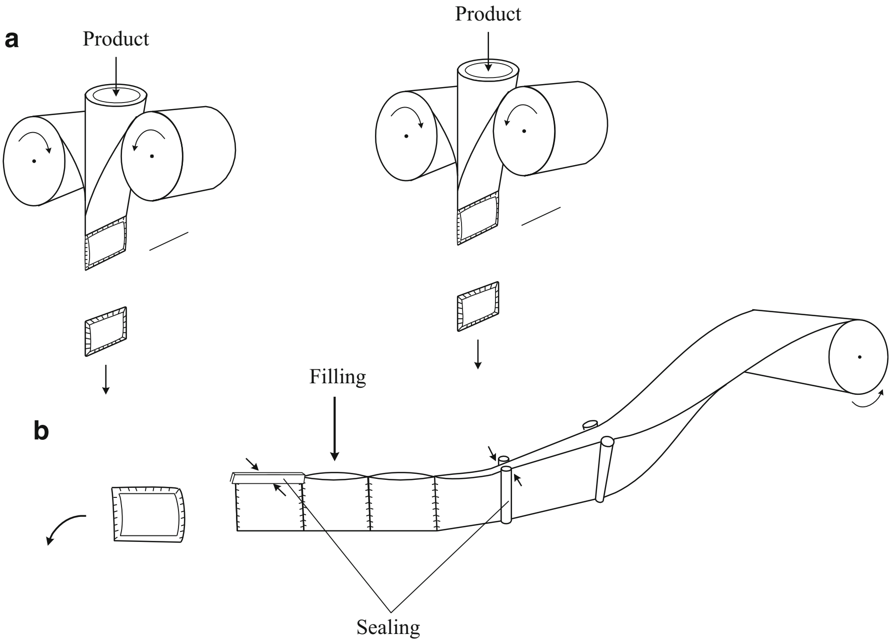


Fig. 13.9 Forming of pouch packages Horizontal, (**a**), and Vertical (**b**), filling of pouches

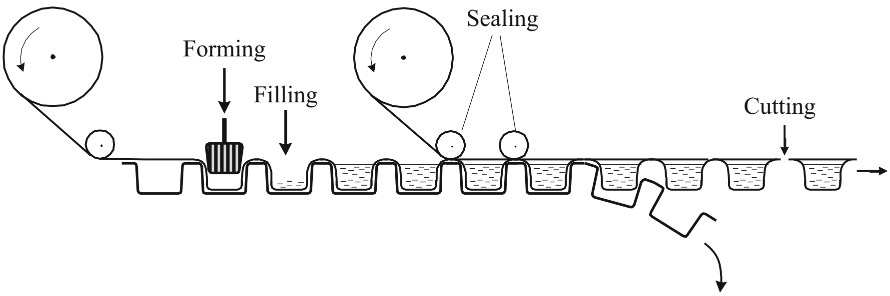


Fig. 13.10 Thermoforming, filling, and sealing of cups

(IR) radiant panel heater (Robertson 1993), or heating takes place in the mold. The heating temperature is about 155–160 °C (Harrison and Croucher 1996).

The thermoforming is done in one of the following ways (Fig. 13.11): Air presses the preheated soft film in the mold (Fig. 13.11a). Negative pressure is applied between the mold and the heated film sheet (Fig. 13.11b). A heated plunger presses the film in the mold (Fig. 13.11c). A plunger pushes the stretched film in the mold, while pressurized air is blown on the film (Fig. 13.11d). At the same time, the air of the mold is sucked out through a hole at its bottom.

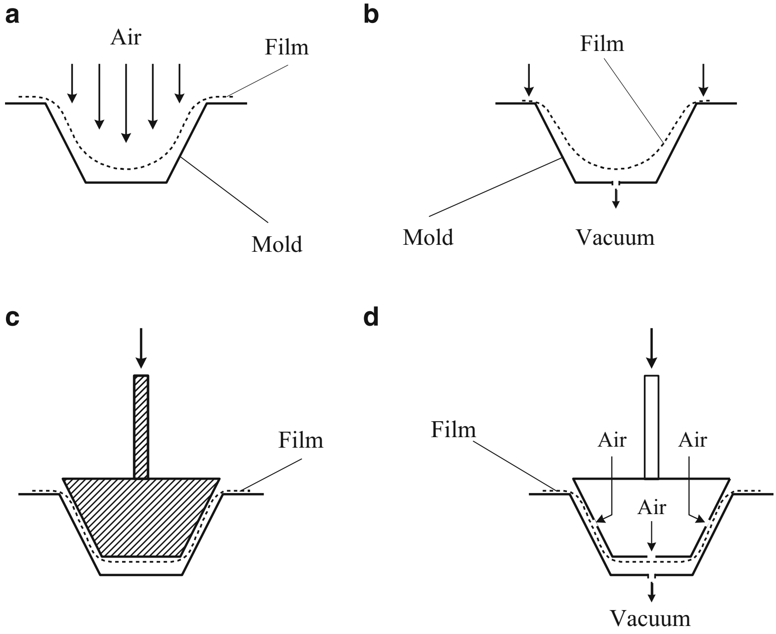


Fig. 13.11 Thermoforming processes of cups: (**a**) to (**d**) (see text)

The space between the plunger and mold is exactly that of the wall and the bottom thickness of the cup that will be created. The air, besides forming, also cools down the formed cup. The thickness of the laminated plastic material that is to be thermoformed depends on the package that will be produced (physical properties, strength), e.g., 75–200 μm (Robertson 1993). For most frozen food applications, e.g., Harrison and Croucher (1996) suggest the following combinations: bottom web, 125 μm (nylon 75 μm and polyethylene 50 μm), and top web, 70 μm (nylon 20 μm and polyethylene 50 μm). Nylon, or in some cases regenerated cellulose, is added for providing the necessary rigidity. The thickness of polyethylene must be at least 50 μm for leak stability (Paine 1996). The capacity of a cup thermoforming equipment depends on the number of the parallel molds, the thermoforming method applied, and the packaging material used. Usually, it is about 6000–8000 packages/h for cups 20–40 mm deep. The deeper the cup, the lower the capacity. The power requirement is 8–10 kW. The pressurized air consumption is 24–30 L/h (6 bar), and 300–400 L/h water is required for cooling (12–15 °C). The dimensions, including the filling and sealing section, are 5.0 × 1.5 × 2.0 m and the weight is about 2 tons.

Blow-Mold Packages

This method is used for filling liquids in plastic containers. The forming and filling of containers are almost simultaneous. The containers are formed by extruding

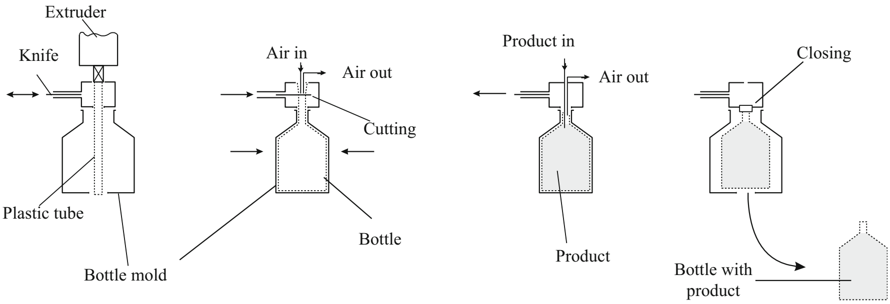


Fig. 13.12 Blow-mold formed package

powder plastics in molds, in which air is blown (Fig. 13.12). The mold consists of two parts. When the blown material takes the form of the mold and it is cooled, the two parts of the mold go apart and the ready package is removed. Blow-mold equipment can produce and fill low-viscosity products, about 400 bottles/h (1 L/ bottle). At this capacity, the electrical energy requirement is about 12 kW, and the pressurized air consumption is up to 100 L/min (10 bar). The dimensions of such machine are 1.5 × 1.5 × 2.5 m.

13.3 Filling Equipment

13.3.1 General Characteristics

Filling of food is a very important processing operation, since it can directly influence the shelf life of the packed products and the precision of the information printed on the package. There are several systems of food filling in containers (metal, glass, plastic, etc.). In all cases, the main aim is to bring the products safe into the containers, satisfying also the declaration printed on the package about its contents. If food is not filled properly, contamination of fresh or frozen products, or recontamination of already pasteurized or sterilized food, can occur. Furthermore, if the package does not contain the right quantity or the right combination or constituents of food, it violates the labeling laws. Therefore, as explained below, several techniques have been developed, overcoming these difficulties.

Generally, the following aspects are important in filling of food in packages: (1) hygienic (sanitary) conditions, (2) coordination with other related packaging steps, (3) high capacity, (4) no waste of product, (5) precision, and (6) flexibility.

In securing hygienic conditions, measures must be taken that the food will not be contaminated during filling. These measures refer to the construction of filling equipment, the environment of filling equipment, and the packages used. The constructional measures include the selection of the proper material and the choice of solutions for reducing the accumulation of microorganisms and facilitating the cleaning of the filling valves and the other parts of equipment contacting with food. To reduce the danger of environmental contamination, food must be filled as soon as possible in the container. Depending on the container and the product that has to be packed, special measures must be taken for not allowing aerobic microorganisms to enter the container during filling. Such measures are, e.g., the sterilization of containers and the filling under controlled atmosphere conditions. For the sterilization of containers, steam, hot air, or chemicals can be used. For reducing or eliminating the danger of environmental contamination of the products, steam or hot air in slight overpressure, vacuum, modified atmosphere, or aseptic conditions can be applied. For securing hygienic filling conditions, the equipment must be cleaned frequently and thoroughly. Therefore, CIP and easy and fast dismantling of the parts that cannot or are not cleaned by CIP should be provided.

The coordination of the different packaging operations, as well as the coordination between packaging and the other food processing operations of a food factory, is essential. A delay in any of the processing steps (forming, filling, sealing, etc.) may paralyze the whole packaging line. Therefore, for achieving a good synchronization of the different packaging steps, adjustments on each packaging equipment should be possible. Furthermore, the equipment of a packaging line should be able to "cooperate" with equipment of other processing operations. For example, excessive product should be prevented from coming to packaging, resulting in a bottleneck. On the other hand, if the removal of packed food does not keep in step with the packaging line, a bottleneck will be created. Solutions such as, e.g., the use of buffer round tables, accumulating packed or non-packed food for a short time, or diversion to other packaging lines, should be foreseen, for the case that a packaging line would be temporarily out of operation for repair, due to sudden malfunction.

The output of filling equipment is related to the average and to the instantaneous output. The first gives the average production rate (packages/min) in a certain production shift, and it is needed to estimate the planned production. The second gives the rate (e.g., packages/min) under steady-state conditions and it is the output that equipment manufacturers state in their guarantees (Perry and Green 1997). Usually, packaging processes are fully automated, resulting in a high capacity. However, the higher the capacity of the equipment, the greater the reliability requirements must be. That means that the service rules must be followed strictly.

Care must be taken to avoid overflowing of food, during filling. If the movement of the containers or their filling is not gentle, product may spill around the containers, which, besides material loss, will soil the filling area, creating a source of microbiological contamination.

Most food processes do not require high accuracy, packaging being an exception. The filling equipment, like most of the rest of machines of a packaging line, must work precisely. Besides the necessity of coordination with other packaging machines, the quantity of the product filled must be in agreement with the label declaration of the container. The modern packaging systems have the possibility to keep the weight tolerance borders narrow. However, since products consisting of nonuniform pieces are difficult to keep in such narrow borders, a slight move of the filling set weight toward the upper weight tolerance is recommended. Precision is also required in the way that several solid foods or mixed products are placed in the package. Frozen fish fingers, e.g., must be placed one besides the other gently, single fruits are placed in specially designed receptacles avoiding any bruising, and ready meals are placed in separate position of the same package (e.g., tray). More care and accuracy is required for packaging of fragile or delicate foods, such as fine bakery and confectionary products and eggs. In the last years, the use of robots in such operations has increased considerably.

A filling machine must be flexible. In food factories manufacturing seasonal products, a filling machine has to be adjusted to process different foods. In some cases, this adjustment has to be done fast. If frequent adjustment is required, the filling equipment must be also robust.

Factors influencing the choice of filling equipment are (1) product that has to be filled, (2) filling conditions, (3) capacity, (4) packaging material, and (5) packaging appeal.

The flowability of food is very important in filling. Food that has to be filled can be liquid, solid, or mixtures of liquid and solids, gas and liquid, and gas and solid. The solid food can be in the form of granules, powder, or pieces. Mixtures of gas/liquid and solid/gas exist, e.g., in bottles or cans of carbonated drinks and bags with coffee, respectively. Low-viscosity liquid food (e.g., beverages, oil, etc.), most granulates, and a part of powders have a high flowability and they can be transferred by gravity. High-density liquid food, such as concentrates and some granulates and powders, may need additional force to flow. In this case, the product is transferred by positive or negative pressure (vacuum) or combination of these conditions. Increasing the temperature can increase the flowability of viscous liquid food by reducing the viscosity. Honey, e.g., can flow easier if it is heated. The flowability of some products can be also improved, if special measures are taken. The flowability, e.g., of raisins which are sticky, is increased, if they are dipped in oil and then dried, and that of salt is improved if permissible additives are used (Domke 1977).

Two main methods of filling of liquids (e.g., juice) are practiced, the cold and the hot filling. In cold filled juices, the aroma and vitamin loss is minimized, and thus the products can justify premium price. A disadvantage of cold filling is the requirement of refrigeration facilities. In the hot method, applied to juice, the product is pasteurized before filling, which occurs at a temperature above 82 °C (Castberg et al. 1997). Cooling is done after sealing. A similar procedure is followed in the sterilization of fruit in cans. The application of vacuum or modified atmosphere and the aseptic filling influence the choice of the filling equipment.

The capacity requirements influence the choice of filling equipment. Filling systems, in which pressure and suction (vacuum) are combined, have high capacity. For liquids, hot filling is faster than cold filling. If higher capacity is required, monoblock equipment, or carrousel, instead of in-line filling, is preferred. In filling of powders, suction systems are preferred, since pressure filling could increase dust and the danger of explosion in the packaging room.

Packaging materials influence the choice of filling equipment. High filling and sealing capacities are required, especially if packages have to be formed in adjusted equipment, shortly before filling. Plastic materials are widely used, especially in connection with small bag and carton packages. Filling and sealing of these materials is simple and high output is possible. The glass and metallic containers come ready to fill, and therefore, the capacity of the corresponding filling machines can be very high, if several filling heads are used.

The packaging appeal may also influence the choice of the filling equipment. Special measures must be taken, when powders or difficult flowing solid products must be filled in bulk. Bags, containing powders or material with high average particle length to particle width (e.g., 1:500), may look "half empty" after filling. This happens because the very low bulk density of such needlelike products immediately after the filling (e.g., for flour, less than 0.4 ton/m^3) increases when the bags are transported and stored. Therefore, care must be taken for increasing the bulk density of such products before or during filling. Due to flowability requirements and since the time between filling and sealing is very short, it is difficult to find a satisfactory filling solution, whenever high filling rates are required. Measures commonly applied are high-frequency vibration (e.g., 20–60 Hz), increasing the packaging density by more than 30 %, compression before or during filling, and shock compression (Domke 1977; Perry and Green 1997). Filling operations of food may be also part of the final processing of viscous foods, when the packaging medium is eatable (e.g., sausages, Fig. 13.13) or deals with filling food in "containers" of any type.

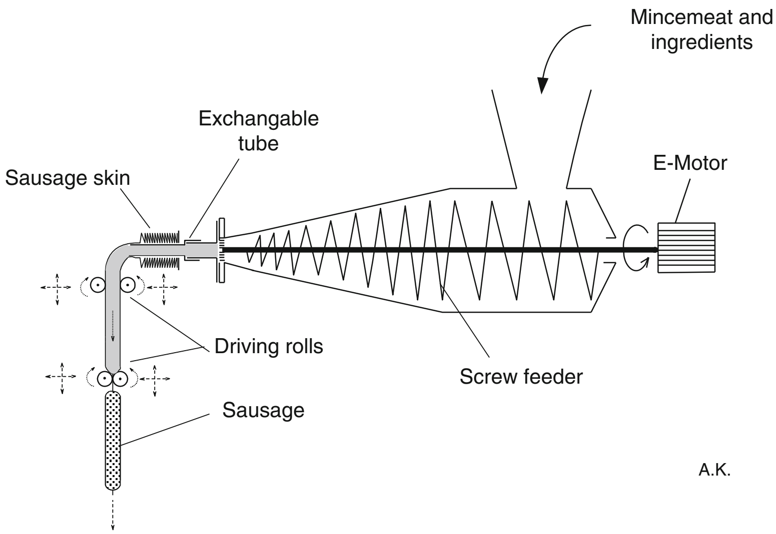


Fig. 13.13 Filling of sausages

13.3.2 Dosing

A filling process may be simply the transfer of food into the package, or it can be a more complex operation. Dosing is an essential part of filling, determining the quantity of a product that has to be filled in a certain container. This operation can be done by the following methods (Fig. 13.13): volumetric filling, filling to a certain level, weight filling, time-controlled filling, and counting filling.

(a) The volumetric filling equipment (Fig. 13.14a) is the most commonly available system. It is used in filling low- and high-viscosity foods. The filling accuracy is reasonable and the speed of filling high. In the volumetric filling, the filler transfers the product to a container until a predetermined volume is reached. The volume can be controlled, e.g., either by measuring the flow rate of the product or by using containers of known volume, in which the product is pre-filled. The high-capacity machines have more than one volumetric filling heads.

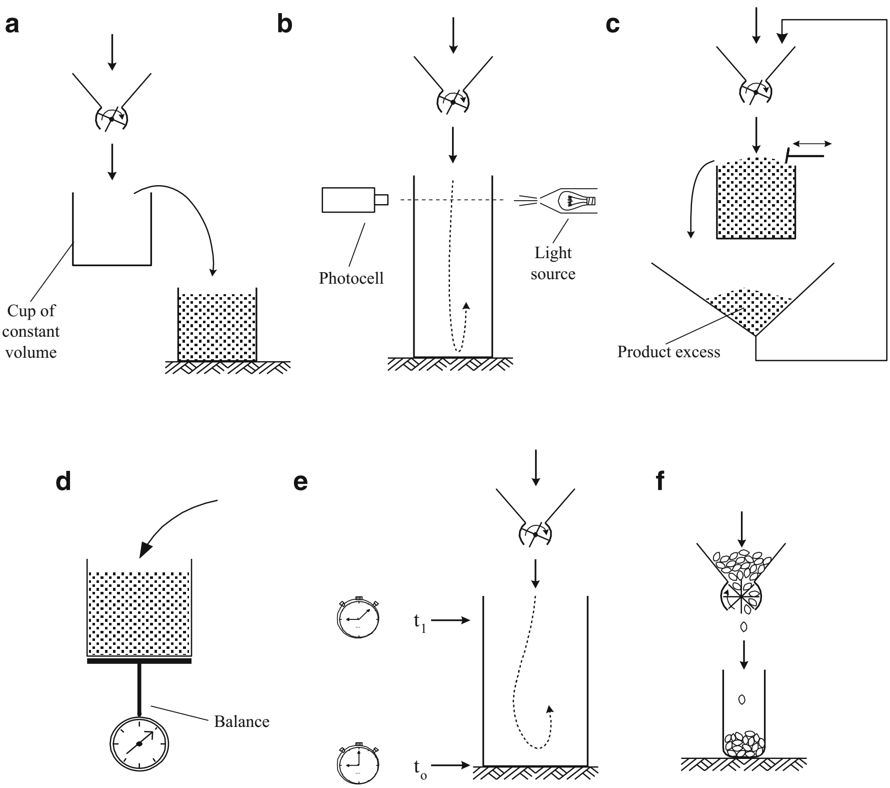


Fig. 13.14 Systems of dosing in filling of foods in packages: (**a**, **b**, **c**, **d**, **e**, **f**) (see text)

(b, c) In the filling to a level system (Fig. 13.14b), the product flows until it reaches a certain height in the container. This type of filling is mainly used in filling liquids in transparent bottles, because consumers usually associate the volume of equal liquids and containers, with the level in the container. The filling stops, when, e.g., a beam sent through the bottle to a photocell on the other side is interrupted by the rising liquid. A special case is the maximum filling, in which the container is filled up to its maximum. Any overflowing excess material is collected and recycled (Fig. 13.14c).

(d) In weight filling (Fig. 13.14d), the weight of the product is checked continuously before filling, or filling and weighing are done simultaneously. In the pre-weighing system, the weight of the product is checked as it is carried, e.g., on belts (Fig. 13.22) or as it moves along in cups of known tare, which are part of a scale. When the weight of the product in the cup reaches the preset weight value, the food is emptied automatically into the container. This system has been highly developed, because of the progress in computer techniques. Modern systems consist of a group of electronic balance cups, transmitting the weight information to a microprocessor, incorporated in the weighing unit. This unit can be part of the filling equipment or it can stand alone.

(e) The time-controlled filling (Fig. 13.14e) is used in filling small amounts, when the properties of the product, the container, and the speed of filling remain constant. However, since all these variables cannot remain absolutely constant, the accuracy of the weight of the product is not very high.

(f) Counting filling (Fig. 13.14f) is used in packaging pieces of food. It is used, e.g., in filling fresh fruits and vegetables, such as oranges, lemons, garlic, onions, etc., in small net packages, pieces of fresh or frozen meat or fish in trays, and pieces of processed food, such as creams, chocolates, meatballs, etc., in containers. The method is used, when accuracy of the weight of products is of minor importance.

Usually, the filling equipment includes the sealing units and, in some cases, the forming of packages. In filling, the capacity of machines varies considerably with the product. The capacity in filling of preformed packages with liquids is high, as well as that of filling cans. The capacity falls when the viscosity of the product and the weight of the package increase. Some examples of technical data of filling equipment are:

1. Filling/sealing of jars with jam or honey (rotary action): 5000–25,000 jars/h. Energy requirement, 4 kW; compressed air, 500 L/min; dimensions, $1.5 \times 2.0 \times 2.0$ m; and weight, 4–5 tons.
2. Filling and sealing of plastic cups with yogurt, cream, liquid soups, fruit jelly (cup diameter/height: 95/130 mm): 2000–25,000 cups/h. Energy requirements, about 40 kW; air consumption, 120–150 L/h (6 bar); dimensions, about $6.5 \times 4.0 \times 3.5$ m; and weight, about 5 tons.
3. Filling of bottles: the capacity of filling equipment depends on the number of filling heads (fillers). For a given filler type (e.g., carrousel), it increases almost

linearly with the number of fillers. A carrousel bottle filling equipment, e.g., with 16 fillers, has a capacity of 8000 of 1-L bottles/h. Equipment with 32 fillers has the capacity of 18,000 bottles/h and equipment with 64 fillers the capacity of 36,000 bottles/h. In the food industry, there are units with more than 180 fillers. Dimensions: diameter, 1.5–3.0 m; height, 1.5–2.0 m; weight, 1.5–4.0 tons; power requirement, about 2–7 kW; air consumption, about 50–100 L/h.

4. Carrousel filler of particulate products (mushrooms, grain corn, meatballs, diced tomatoes) with 30–45 filling stations. Maximum range of containers dimensions 191–127 mm. Range of maximum output: 40,000–60,000 cans/h. If the filling stations increase to 60, the output for free-flowing products (e.g., juice or milk) can go up to 90,000 containers/h.

13.3.3 Product Transfer Systems

Basic elements in dosing are the product transfer system, the containers, and the filling valve. The product must be transferred steadily to the control unit (volumetric, weight control, etc.) and subsequently to the filling valve. The valve opens, letting a certain amount of product into the package, only if a container is already there. The synchronization of the container arrival with the opening of the filling valve is essential.

There are two main systems in conveying round containers to the right filling position, the in-line and the rotary wheel system (Fig. 13.15). In the in-line system, the containers come to certain belt positions under the filling unit (Fig. 13.15a), or they are conveyed by a rotating wheel (Fig. 13.15b). Belts are used to convey also

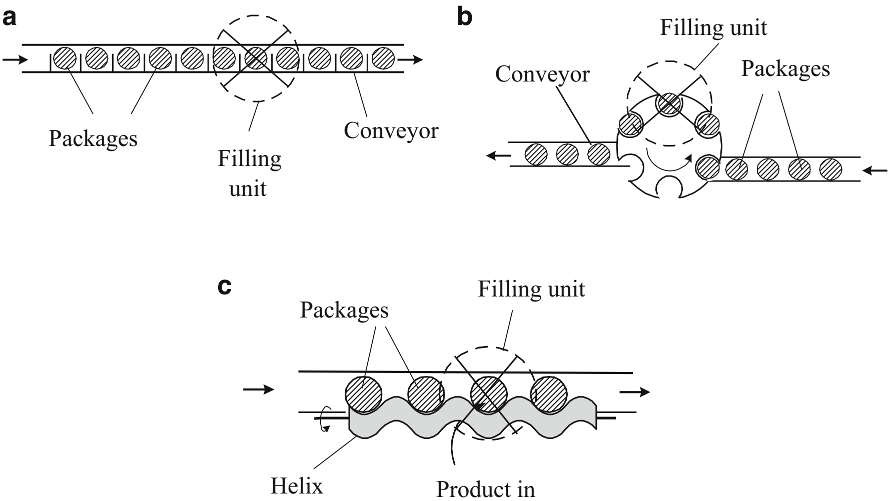


Fig. 13.15 Container conveyance systems to the fillers. (**a**, **b**, **c**) Different types of the relation: Filling unit-Container conveyance system

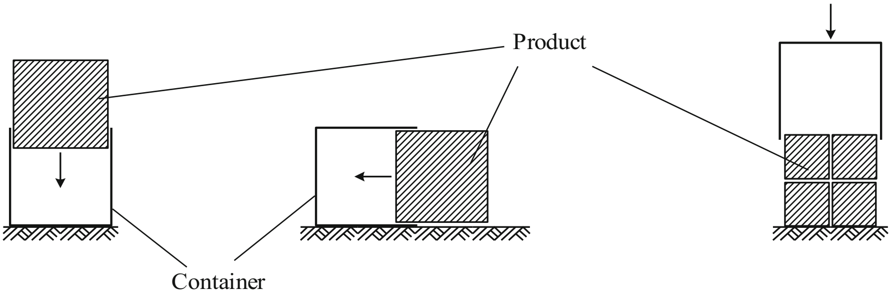


Fig. 13.16 Inlaying of products in packages. (**a**, **b**, **c**) Different systems of inlaying products in packages

containers of other shapes. The speed of the rotary helix system (Fig. 13.15c) is higher than that of the wheel system. The synchronization is done through adjustments in the speed of the belt or the rotation of the wheel and the helix, respectively.

The position of the package, in relation to the product that will be filled, depends on the product and the filling method (Fig. 13.16). Usually, packages are under the filler (Fig. 13.16a), but in some cases of solid materials, the containers may be on the side (Fig. 13.16b), as, e.g., in the filling of a certain number of frozen fish pieces in cartons. In some other cases, the containers come downward over the product, as, e.g., in packaging of prearranged food. In the last case, the package and its contents are turned over before sealing (Fig. 13.16c).

The systems used in transferring food into containers depend on the nature and the consistency of the products. Basically, transfer can be done by (1) gravity, (2) pressure, (3) isobaric transfer, (4) negative pressure (vacuum), and (5) combined transfer.

Gravity is used when the product flows easily, as in the case of low-viscosity liquids and nonadhesive granules. It is especially useful when processing goes from upper to lower floors. Pressure can be applied almost in all cases. It can increase the flow rate of flowable products and the transfer of viscous food. Isobaric transfer (constant pressure during transfer) of food is useful when the products are sensitive to pressure gradients. Negative pressure (vacuum) is applied in sucking liquids, granulates, or powders up to the filler. High airtightness is required, when the product is easily oxidized or contamination with aerobic microorganisms may occur. The combined processes counterbalance the negative points that each method may have, when applied alone. Pressure systems, e.g., may be more economic, if product transfer is also gravity assisted.

Pressure is applied to liquids or viscous products by pumps. Piston, diaphragm, gear, screw, and rotary pumps are normally used (see Chap. 3). These pumps, besides product transfer, are an essential element of the volumetric and the time-controlled dosing systems. Piston pumps are very common, operating exactly like gear pumps, and can transfer certain foods of varying viscosity at a steady rate. The diaphragm pumps, as well as the gear pumps, are both used in dosing. They work accurately, but the diaphragm pumps are used in transferring smaller quantities and less viscous products. The screw pumps, as well as the rotary pumps, are used in transferring larger quantities of liquids, granules, and powders. The sensitive products are conveyed by belts and vibrating surfaces (Chap. 3). These conveying systems are also used in connection with weight filling. When exact weight is required, a system of belts or vibrating surfaces is used, in which there is a differentiation in the speed or in the vibration of each conveying element.

13.3.4 Valves

Several types of valves are used for filling liquid and comminuted solids. In some packages, e.g., bags and drums, used in aseptic filling, the valves are integrated in the packages. In bottle filling, the valve of the filler opens automatically, when the filler passes through the mouth of the bottle and reaches a certain position (Fig. 13.17). Usually the bottles are lifted by pistons progressively (Fig. 13.18). At the same time, the valve of the filler opens gradually and the liquid enters in the bottle, while the air in the bottle is discharged through a concentric tube. The filling of larger containers is often done in two stages: (a) the largest amount is filled quickly, and (b) the product is added to the partially filled container, until it reaches the preset amount. Usually, in powders and granulates, this additional quantity is conveyed by vibrating devices. In liquids, the additional quantity is controlled by varying of the aperture of the filling valve.

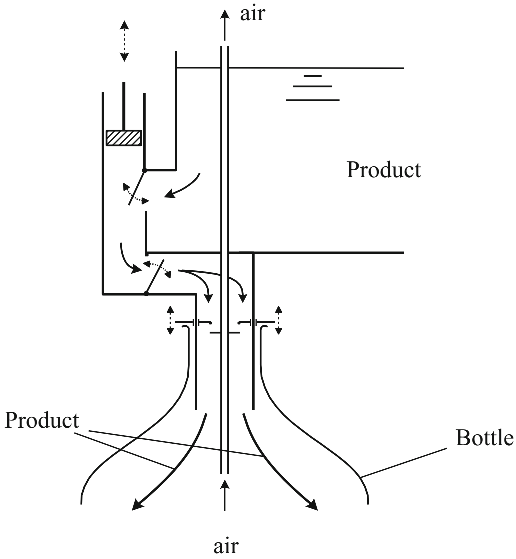


Fig. 13.17 Principle of bottle filling valve

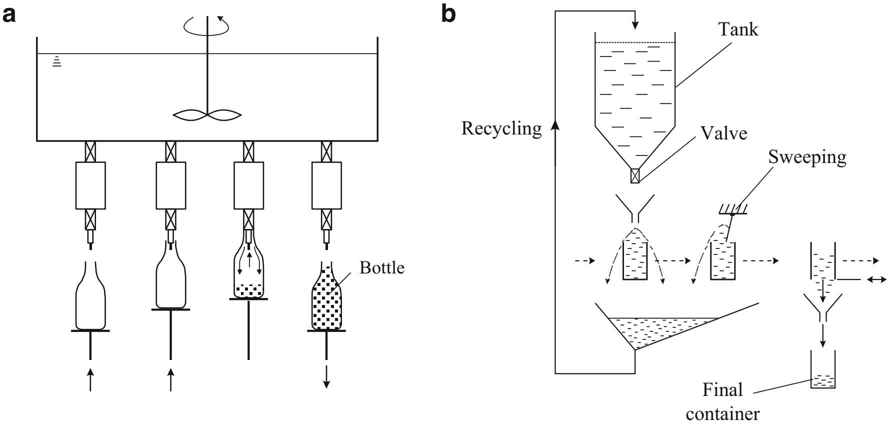


Fig. 13.18 Exact filling of bottles (**a**) and subsequent control, in filling of packages (**b**)

Depending on the type of filling, the liquid flows in the bottles by gravity, by pressure, or in an isobaric way. The bottles are vacuum-filled, if the concentric tube of the filler is connected to a low pressure system, which sucks the air of the bottle, resulting in the inflow of the liquid. The same tube may be used to introduce gas (e.g., carbon dioxide) in filling carbonated drinks. In some filling systems of bottles, carbon dioxide is also used to push the air out of the container before filling and to equalize the pressure between bottle and surroundings until the bottle is filled.

In the filling of granulates and powders, the flow of the products from a chute is controlled by gates and other devices such as augers. Figure 13.19 indicates some kinds of such gates. In filling of granules or powders, it is also possible to use a pre-filling container matching the exact volume that has to be filled. The pre-filling container is fixed on a carrousel. In the first step, the container is filled up completely, while in the second step, any excess product is "swept" away, and the overflowing product is recycled. In the third step, the pre-filled container is emptied into the package (Fig. 13.16b). This method can be used only in nonsensitive and flowable products, such as rice, lentils, etc. If rigid containers are used (e.g., metal cans), the sweeping of the excess product can be done directly on the final container.

In filling of fruits, olives, and several kinds of small vegetables, a possibility is to use ducts or round conical stainless steel tables, with round holes matching the position of the containers underneath (Fig. 13.20). The product that is discharged on the table is forwarded toward the holes, filling the containers. Valves (e.g., gate or rotary) stop the further flowing, when certain weight or volume is reached. For checking the weight of each container, load cells, on which the containers rest, are connected to microprocessors. When liquids with particulates are filled, the type of dosing equipment determines the maximum size of particulates that can be filled along with the liquid. By using piston fillers, the particulates should not exceed 25 mm and, for rotary pumps, 12 mm (Buchner 1995). Lobe and screw pumps

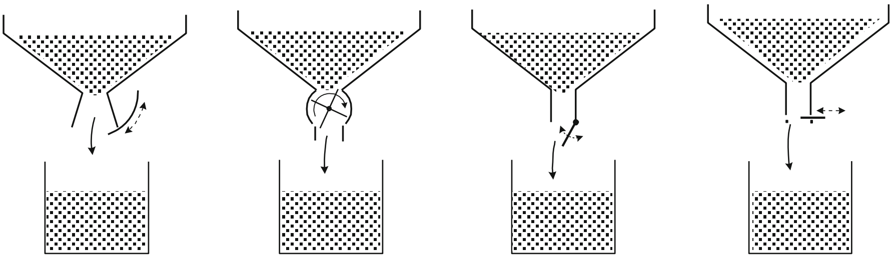


Fig. 13.19 Filling of granules and powders

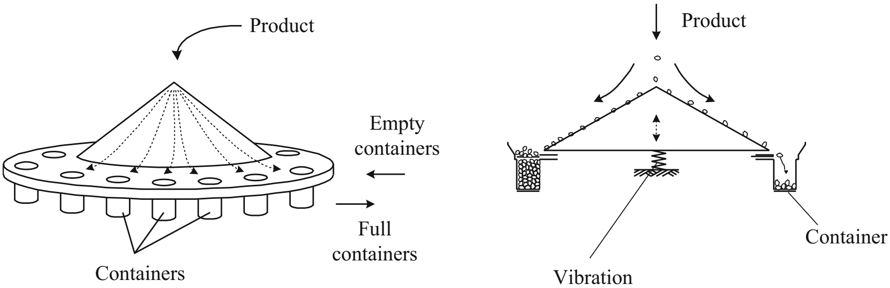


Fig. 13.20 Filling of fruits in containers

damage solids, if they are larger than a few mm. When particulates are large (e.g., peach halves in syrup), the two components are filled in the container separately.

The filling of liquids is done from the top of the containers (e.g., barrels). However, if a product can be easily oxidized, then filling starts from the lower part of the container, so that the filler is always dipped in the liquid. Finally, the filler is elevated as the liquid level goes up (Robichon and Savina 1996). The filling from the bottom is also recommended, when flammable liquids are filled. In the filling of flammable liquids and powders that may cause explosions, standardized safety regulations must be followed. For explosion-proof operation of, e.g., powders, there are the European Standards EN 50.0014 and EN 50.016 with classification EEXPIIT 3.

13.3.5 Weighing

Weighing scales are used to check the weight of the product before or after filling. The weight of the empty or filled packages can be measured during transport, using, e.g., conveyor scales. In the same way, conveyor scales can weigh larger containers (e.g., barrels) during filling (Fig. 13.21). A variation of the small-package conveyor scales has also the possibility to sort packages according to their weight, conducting

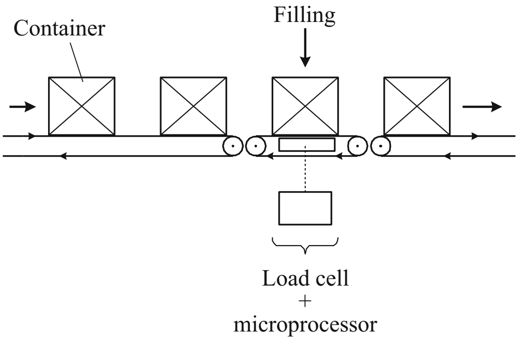


Fig. 13.21 Continuous weighing during conveying

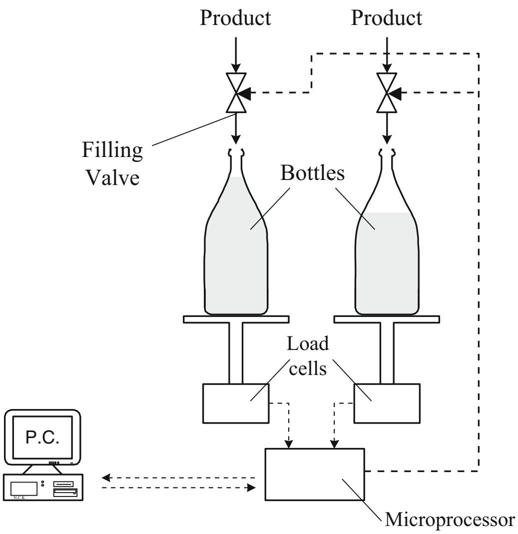


Fig. 13.22 Continuous weighing during filling

them to different conveyors, after weighing. Scales are often part of complex packaging equipment. In bottle filling and closing equipment, the bottles are weighed during filling, since each bottle rests on a load cell individually. The information about the actual weight is sent to a microprocessor and a PC system, which controls the filling process. This way, any required adjustments in filling, e.g., due to deviations in the density or the temperature of the product, are executed automatically (Fig. 13.22). Scales are also used in calculating the net weight of the product. This is necessary, if the tare is not constant and, therefore, the filled quantity has to be steadily adjusted.

By weighing powders, granulates, and small pieces continuously, the scales act also as dosing equipment. For quick and accurate weight measurement, multihead balances are used (Fig. 13.23). Such units may have 3–24 scales ("cups"). They consist of a vibrating cone, linear feeding pans, two rows of cups, and a collecting chute. The feed to the balance is distributed around evenly by the vibrating cone.

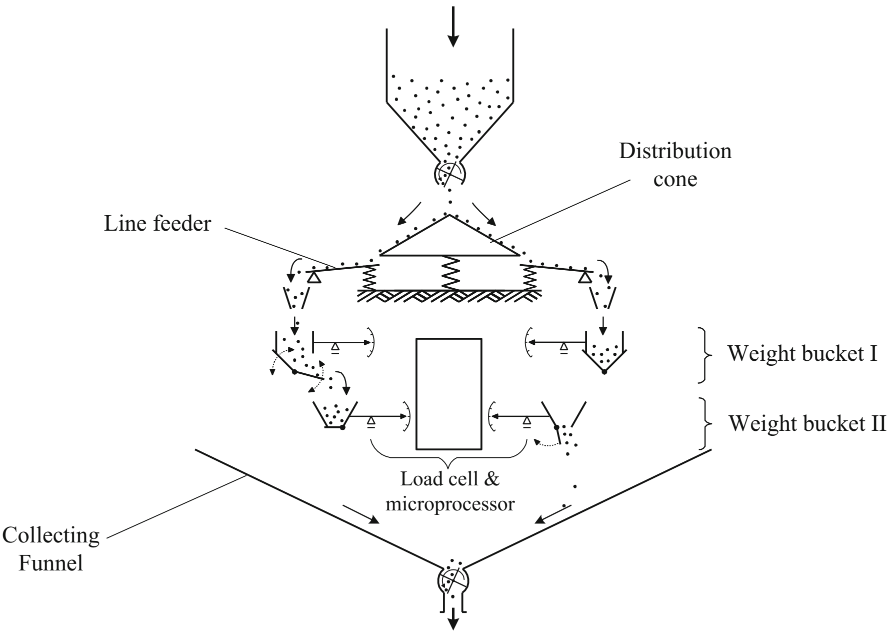


Fig. 13.23 Multihead weighing

The product comes to the linear feeder pans, which transfer it by vibration to feed buckets. Microprocessors collect the weight information of the weight buckets continuously and, through a computer, calculate the best bucket-content combination, approaching the set weight value. If the calculated weight combination is acceptable, the weight buckets open and this amount is transferred to the chute and then to the collecting funnel. A valve then sends the product of each combination to the filler. The buckets whose contents did not match the set value in any combination are emptied in the weighing buckets below. The upper weight buckets are refilled and any new bucket combination, matching the preset weight value, is again emptied in the collecting chute. Such scales can also be used for exact mixing of products (e.g., different small pieces of vegetables) in predetermined analogies. The weights are also delivered as twin units. These have double collecting funnels, enabling two different kinds of weighing at the same time (e.g., simple and mixed product weighing).

Table 13.2 gives some data for multi-weight and conveyor scales. The maximum weighing capacity and the weighing speed are larger in the multi-weight scales.

The weighing capacity of conveyor checkweighers can vary from a few grams to several kilograms. In weighing of food, it is possible to choose among several weight capacity categories, e.g., scales for up to 1, 5, 50, and 150 kg. The smaller the weight capacity, the higher the accuracy and the weighing speed (number of weighings per min). The weighing speed of multihead scales (e.g., 16 heads) is 150–200 weights/min. The dimensions of a conveyor scale, without the auxiliary

Table 13.2 Technical data of weighing scales

	Multi-weight scale	Conveyor scale		
Max. weighing capacity (kg)	1	5	35	150
Weighing range (kg)	0.01–1.0	0.05–5.0	0.04–35.0	1.5–150
Weighing speed (weight/min)	200	150	120	100
Accuracy (g)	0.5–1	0.1	1	4
Volume (mL/package)	4000			

feeding and takeaway conveyors, are 0.5 × 0.4 m (the height is adjustable), and the weight of a unit is about 100 kg. Usually, the multiscale units are placed above monoblock units. The height and the diameter of a multihead scale are 2.0 m in packaging FFS equipment. In this case, the total height is about 4.0–5.0 m.

Weighing in connection with modern computer techniques is also useful or even indispensable in several food manufacturing processes from raw material delivery up to the creation of final products. In several cases, weighing also contributes in the choice and the appropriate adjustment of processing equipment. In connection with the incoming raw materials and weighing, besides economic considerations, it is also part of instrumentation applied in classification and logistic operations. Such an example is the estimation of the humidity of incoming raw corn products requiring drying prior to their storage in silos.

In connection with processing operations, weighing may be used, e.g., in estimating the relation of the further processed, to the rejected products. This may reduce losses by introducing better adjustments of equipment used in processes such as peeling, cutting, and screening. Finally, correct weighing before further processing improves the final quality of products when it is applied in connection with formulations or in connection with the initial quality of products. Such examples in fruits are the relation weight–color and weight–texture and slicing or portioning operations and the relation between weight and meat fat content.

13.4 Closing Equipment

13.4.1 Closing of Food Packages

The methods of closing packages of food depend on the (1) packaging material, (2) food in the package, (3) processing and storage conditions, (4) packaging equipment, and (5) strength required.

In glass and metal containers, closing is done by mechanical means. This is, e.g., the case of closing glass containers with metallic or plastic caps and the double seaming of cans. Plastic packaging or combined materials, such as plastic-laminated aluminum and cardboard paper, are mainly heat-sealed. Paper and cardboard packages are closed with adhesives or by mechanical means (e.g., sewing). The method of closing is also influenced by the food contents. If, e.g., food in a glass or paper package must be protected from air oxidation, heat sealing is applied besides capping, and plastic-laminated aluminum is additionally used. The materials used in closing containers must not affect the food. This is especially important in selecting the proper adhesives or sealing materials being used in connection with caps. Processing and storage conditions play also a role in selecting the proper closure. Seaming must withstand high pressure during sterilization of cans, and the adhesives, used in closing of cartons, must withstand the low temperatures during freezing and storage. Closures must withstand the mechanical stresses exercised by packaging equipment, since mechanical and thermal stresses during capping, seaming, and sealing are unavoidable. A closure, in a broader sense, is a joint between two packaging materials. All joints are especially burdened by mechanical stresses, during handling and storage. Closures must withstand this stress, especially when there is a pressure difference between package contents and environment. The equipment used in closing of packages must be able to meet all the above challenges.

13.4.2 Glass Closures

In glass containers, the joints are only in the closure of the container. The elements used are metallic caps, plastic caps, and cork. Since glass is inert, there are no problems due to the contact of different materials. However, since glass is rigid, the cap used must be flexible enough to resist mechanical stress and maintain tightness. This is especially important, when pressure differences between the container contents and its environment exist. The equipment used for closing glass containers is versatile, since often they have been developed in connection with patented cap systems. For wide openings (e.g., jars) with threaded neck or a neck for crimping, metallic closures or covers are used. In both cases, the closures or the cover has a plastic seal for better tightness. This can be a natural or synthetic rubber, a sheet polyvinyl chloride, or other suitable plastic materials (Downing 1996). However, for securing an even better airtightness, a coated aluminum sheet can be sealed on the mouth of the container, below the cap, as well (Hugel and Pajean 1996). For bottles, the crown cap (an invention since the turn of the century) still gives good sealing effect, especially in bottles containing gas/liquid mixtures (e.g., carbonated drinks, beer). However, since the introduction of the one-way bottle with threaded neck, roll-on aluminum caps are used. These caps are also provided with a tamper-evidence ring (Robertson 1993). In closing of bottles, usually monoblock carrousel equipment is used (filling and closing in one equipment). As in the case of the bottle filling equipment, the bottles that must be closed rest on pistons which elevate, press, and twist the bottles against the caps, which come to the closing head, automatically. The capacity of a closing machine depends on the number of heads it has. The output of crown capping equipment, e.g., varies between 3000 and 90,000 bottles/h, if the heads are between 3 and 36. The operation of equipment closing bottles with natural cork is similar. In this case, a 24-head equipment can close 25,000 bottles per hour. The dimensions and the energy consumption of bottle closing equipment are similar to those of filling units of the same output.

13.4.3 Closing of Metallic Containers

In metallic containers, the joints are especially important in the three-piece can. The junction of the can end seams, with the side seam, is a particularly weak point of such cans. However, the three-piece can has been now replaced to a great extent by the two-piece can, in which only one double seam exists. The closing equipment closes a can in two steps, by using two different roller die profiles (Robertson 1993; Downing 1996). During closing, steam is often blown through jets on the surface of the can contents. The steam expels the air and it contributes to the can tightness, due to the vacuum created in the headspace of the can, after the condensation of the steam.

In can packaging of products, such as nuts or several powders, mechanical vacuum or modified atmosphere can be applied. This is done continuously, e.g., in carrousel seaming machines, provided with airtight space for every can placed on pistons automatically (Fig. 13.24). Can seaming machines consist of two carrousels, corresponding to the two closing steps. The capacity of can seaming equipment can be more than 60,000 cans/h. The energy requirement of such equipment is about 10 kW. The dimensions of the machine are about 3.5 × 2.5 × 2.5 m and its weight is 5–7 tons. The capacity of vacuum or modified atmosphere equipment is less, but they require about 60 % more energy.

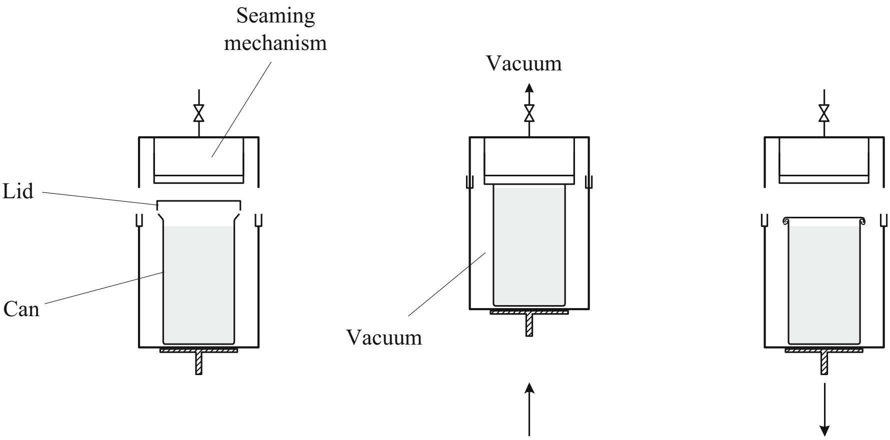


Fig. 13.24 Vacuum seaming of cans

13.4.4 Closing of Plastic Packages

In plastic packages, the sealing technique is used to make packages (e.g., bags) or to close them after filling with food. In larger equipment, sealing is done in a monoblock machine, in which forming and filling also take place. This holds well for tube bags, pouches, and to a great extent cups and aseptic filling or when modified atmosphere is applied. Monoblock equipment is also used in the blow-mold method, in which, besides the formation of bottles, filling and closing take place. The quality of a seal depends on the material to be sealed, its thickness, the pressure exercised during sealing, and the duration of heating. There are two main methods, the hot and the cold sealing, which differ in the temperature and pressure during sealing. Cold sealing is generally faster. In the frozen food industry, cold sealing of the packaging material prevails, since it resists better the low temperatures (Brown 1992). In hot sealing, the temperature depends on the material to be sealed. Sealing in in-line pouch forming is usually at 155–160 °C. When polyethylene with oriented polypropylene is used, the temperature is 110–120 °C, since polypropylene begins to harden above 130 °C (Harrison and Croucher 1996). Electrically heated bars or plates are normally used for sealing. The laminated top film is used in closing plastic cups just after filling. The film is heat-sealed automatically by special bars that are able to seal, e.g., 84 cups at a strike (Buchner 1995). The sealing capacity of plastic cups, for low- to medium-speed machines, is 50–150 packages/min. In cold seaming, the capacity of high-speed equipment can come up to 750 packages/min (Harrison and Croucher 1996). In plastic containers, airtight aluminum covers are used, which are laminated for sealing and increasing the cover stability. The covers may also be crimped mechanically over the edge of the container. In sealing, it is important to have uniform distribution of heat over the whole surface contacted. It is also important that the surface to be sealed is clean and that heating is stopped just before the temperature of the sealing bar or the heating plate exceeds the preset values. In vacuum sealing (Fig. 13.25), the plastic bag containing the product is sealed automatically, when the air in the bag is evacuated. The heating seal heads have Teflon strips to avoid sticking. The pressure

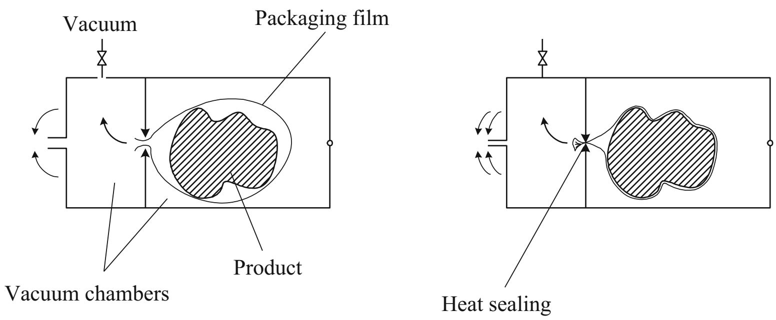


Fig. 13.25 Vacuum sealing of plastic packages

exercised during sealing is about 4 bar. The required energy of a relatively small unit (capacity: 15–40 bags per minute), including the vacuum pump, is 9–15 kW. The dimensions are 2.0 × 1.5 × 1.5 m and its weight, with the vacuum pump, is 500–600 kg.

13.4.5 Closing of Cartons and Cardboard

Coated cartons can be heat-sealed or closed using glue. Heat-sealed cartons are used in packaging of frozen food. When sealed with adhesives, the bonding speed and tack of glue depend on the speed of the gluing equipment, the porosity of the package, and the duration of contact of the surfaces that have to be sealed. Boxes are sealed with adhesive kraft paper or with plastic tapes coated with adhesive. A box tape-closing machine of a capacity of 1500–2000 boxes/h, in which the boxes are sealed with a tape, applied as the boxes are conveyed under it, may consume 2.0 kW of electrical energy and 50 L of air/min, and have dimensions of 2.5 × 0.8 × 2.0 m and a weight of 350 kg.

13.5 Aseptic Packaging

In aseptic packaging, a pasteurized or sterilized product is put in a sterilized container without coming in contact with its environment. Therefore, no additional thermal treatment after packaging is required. However, particular precautions are required to avoid any post-sterilization contamination of the product (Fig. 13.26). These precautions include sterilization and control of the following: (1) chamber in

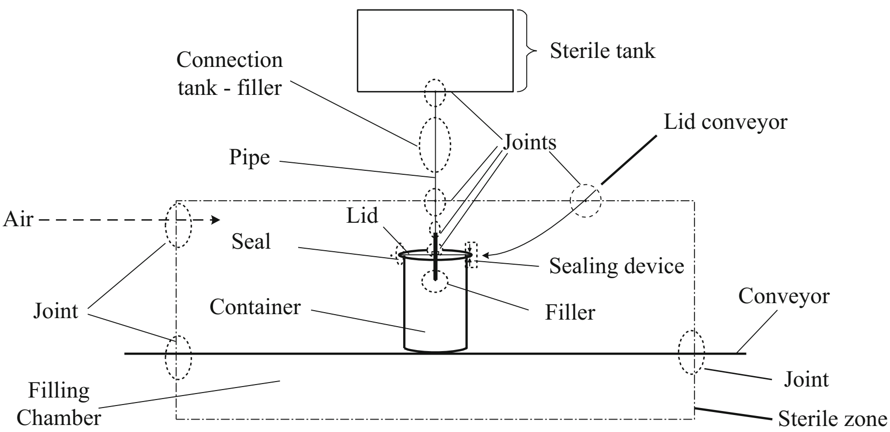


Fig. 13.26 Hazard points in aseptic packaging

which the product is filled and sealed, (2) filler and filling valves, (3) sealing devices, (4) conveying systems, (5) container, (6) air, (7) joints between tubes and chamber, (8) pipe, (9) lid, and (10) sterile tank.

In aseptic systems, precaution should be taken so that uncontrolled air from outside does not enter the chamber during entrance and exit of the containers or due to leakages. Sterilization of the system is accomplished by steam, hot air, chemicals, or ultraviolet (UV) radiation. In the case that blow-mold containers are used, the high temperature during extrusion in creating the containers (180–230 °C, 3 min) reduces greatly the microorganisms, but such containers should be used only in the aseptic packaging of high-acid products (Reuter 1988).

For the sterilization of the filling chamber and the mechanical parts, wet steam at atmospheric pressure can be used, if high-acid beverages are to be filled. Superheated atmospheric steam may be used for low-acid products. In hot air sterilization, the air temperature must be 330–350 °C and the sterilization time at least 30 min. The fillers, which are a very sensitive part of the aseptic system, are sterilized by pressurized steam or superheated water (130–135 °C, 2 bar) (Buchner 1995). They should be also easily dismantled for frequent thorough cleaning.

Chemical sterilization is achieved using hydrogen peroxide and several detergents. These detergents are normally used in cleaning the filling line together with the pasteurization equipment in the CIP (cleaning-in-place) systems.

Packages made of laminated film are sterilized by hydrogen peroxide. The packaging material is sterilized shortly before being used in the construction of packages (e.g., bags) by dipping in hot hydrogen peroxide. The concentration of hydrogen peroxide must not exceed 35 % (Buchner 1995; Robertson 1993). The same hydrogen peroxide method can be also applied to sterilizing film that is further thermoformed to cups. In all cases that hydrogen peroxide is used, it is subsequently removed by blowing sterilized air or by evaporating by means of a hot cylinders (90 °C), contacting the film after sterilization.

Eventual residue of hydrogen peroxide should be less than 0.05 ppm. In hydrogen peroxide sterilization, it takes about 5 min to reach the evaporation temperature and 10 min to sterilize the packaging material. In another method, the film forming the container is delivered pre-sterilized (Robinson 1995).

The metallic rigid containers are sterilized by steam. For tinplated cans and their lids, superheated steam or hot air in the range of 260 °C is used (Downing 1996). The temperature of tin containers is maintained at 220–260 °C for 45 s, while aluminum cans are heated at the same temperature for 36 s (Reuter 1988). For aluminum foil/paperboard "semirigid" containers, used in filling of high-acid products, hot air (116 °C for 45 s) can be used (Downing 1996). Another possibility is to use a combination of hydrogen peroxide vapor and hot air (Downing 1996). Polystyrene plastic cups can be sterilized, immediately after deep drawing, by steam at 165 °C (6 bar) for 1.4 s. Their lids are sterilized at the same temperature for 18 s. The cups are cooled during heating externally, so that no deformation due to elevated temperature occurs (Reuter 1988). The heating of the caps and lids is done simultaneously and just before filling and sealing.

In some sterilization processes, UV radiation can be additionally used, since UV promotes the breaking of the hydrogen peroxide into hydroxyl radicals, increasing the sterilization effect (Robertson 1993). Besides that, light overpressure of 1.0–1.5 bar protects the filling chamber from aerobic contaminants. According to Turtschan (1988), the loss of intensity of UV radiators, used in sterilization of plastic cups, is only 50 % of the initial value, after 3000 h of operation.

Air used in connection with aseptic packaging (e.g., hot air sterilization, automation control) should be cleaned in sterilized filters. The sterilization of the filters can be done by hot air (300–350 °C) and by pressure steam (Downing 1996; Buchner 1995).

In most cases of aseptic packaging, monoblock equipment is used, since this compact unit allows a better control of the processing conditions. The FFS equipment especially has contributed significantly to the expansion of aseptic packaging of liquid foods.

Aseptic packaging processes and equipment are described by Reuter (1988), Wilhoft (1995), and Downing (1996). Basically, the aseptic methods may be subdivided into the FFS methods in which the whole process takes place in the same monoblock equipment and the methods in which single filling and closing equipment are closed in an aseptic environment, in which the sterilized containers are supplied (e.g., Dole and Combibloc systems). The following two examples of monoblock equipment illustrate the aseptic packaging of food.

Figure 13.27 shows the aseptic packaging of the Tetra Pack FFS system. The laminated film that will be used in making the package is delivered in rolls (about 50 kg/roll). This quantity is enough for a 1-h operation when 250-mL T-Brik packages are produced and filled (Downing 1996). From a reel, the film passes through rolls stretching and stabilizing it. Subsequently, the thin strips of plastic material are added on both edges of the stretched film. The strips will facilitate the forming of a vertical seam, when the film is formed into a tube. The film is subsequently sterilized by dipping in hot hydrogen peroxide solution (30–35 % by weight), followed by drying. In sterilization followed by drying, large equipment, producing up to 6000 cartons/h, consumes up to 2000 mL/h hydrogen peroxide (Reuter 1988). Drying is achieved by light compression between two hot rolls and subsequent blowing of sterilized air. After that, the package is formed and simultaneously filled through the tube, as described in "Filling." Shortly, before the tube formed leaves the central filling tube, it is heated once again to 110 °C, for safety reasons. The reel with the film is on the ground level and the reel off is matched to the production of packages. The height of the upper part of the monoblock equipment is 4–5 m and contains the preparation of the film for filling. The height of the lower part is almost equal to the upper, and it contains the forming, filling, and sealing sections. The energy consumption of equipment of the above capacity is 29 kW. It consumes also 27 m^3 of air/h and 2.4 kg of steam/h.

In the Combibloc method (Downing 1996), prefabricated carton containers are formed shortly before their sterilization by spraying hydrogen peroxide in a monoblock equipment (Fig. 13.28). Drying of the sterilized containers is done by sterile hot air (200 °C) blown into the ready-to-fill carton. The sterilized product

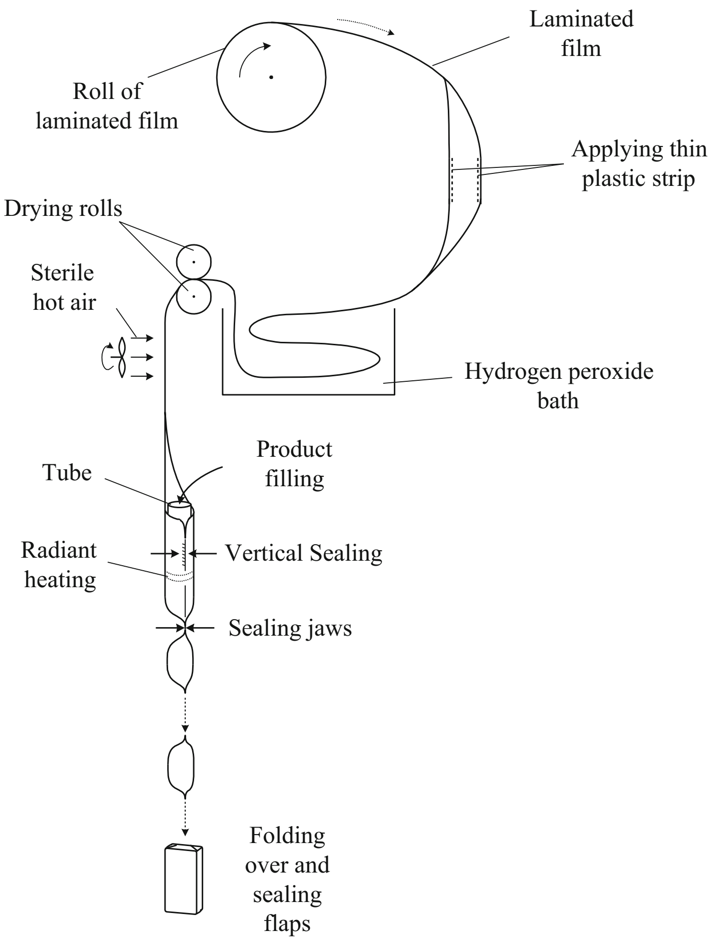


Fig. 13.27 Principle of Tetra Pak system aseptic FFS monoblock equipment

flows from a tank to the fillers. Sterilized cold air is fed into the tank for avoiding the development of a vacuum, while it is emptied. Before sealing the container, steam is blown on the surface of its contents. This results in the creation of a vacuum on the headspace of the container, after it is sealed. The top seal is treated with ultrasonic energy.

In addition to small packages, aseptic packaging is also applied to large containers. Thus, tomato and fruit concentrates are packed directly in large metallic drums or in laminated plastic bags (e.g., 20 kg), which are put in fiber drums for mechanical protection. The drums and the bags come sterilized and sealed. Figure 13.29 shows the aseptic filling of a sterilized container. Basic elements in this process are the container's sealed mouth and the filler valve. The sealed mouth of the container is punched by the filler entering in the bag. At the same time, steam

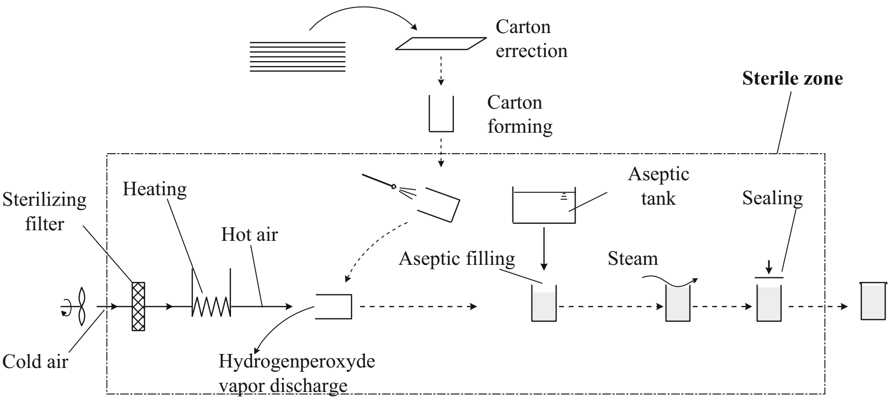


Fig. 13.28 Principle of Combibloc system aseptic packaging

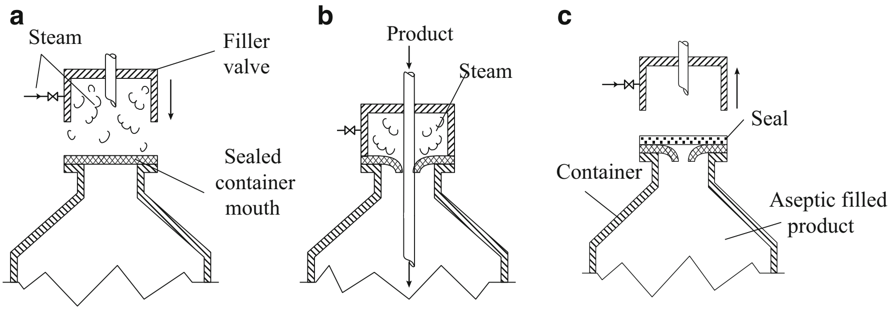


Fig. 13.29 Valve for aseptic filling of sterilized container. (**a**, **b**, **c**) Valve filling stages in aseptic sterilized container

ejected around the filler provides sterility, and due to the overpressure exercised, air does not enter the bag during filling (Fig. 13.29b). When the filler is removed, the bag is sealed in steam atmosphere automatically (Fig. 13.29c). Filling units can fill and seal more than 60 drums/h. The contents of such bags can be used later in further processing.

Larger quantities of aseptically preserved fruit or tomato concentrates can be stored in large tanks (Downing 1996). The storage capacity of such tanks may exceed 150 tons. The smaller tanks (e.g., up to 2–20 tons) can be made of stainless steel. They are often placed in the food processing factory for extending the period of production, in processing seasonal crops, such as tomato. The larger tanks can be also made of concrete that is internally lined with an epoxy-like synthetic resin. Such tanks are installed outside of buildings and are filled with nitrogen after sterilization and sealed up to their filling. The aseptic storage of large quantities makes also possible the processing of certain products far from the area they have been harvested. This is, e.g., done by transporting aseptically filled tanks by trucks or railcars.

The aseptic packaging of products has many advantages since: (1) a great variety of packages can be used; (2) in comparison to other heat treated products, higher quality is achieved, since heat transfer is faster; (3) the process is faster; (4) a variety of heat processes for the same package can be applied; and (5) less heat-resistant packages can be used.

Disadvantages of aseptic packaging are that (1) the method can be applied only to relatively few fluid foods; (2) if solids are contained in the fluid, they must not exceed the size of 25 mm (however, recent developments allow aseptic processing of such suspensions); (3) relatively high investment is required; (4) high safety measures are required; and (5) high coordination of all processing steps must be achieved.

13.6 Group Packaging

13.6.1 Grouping of Packages

Methods and procedures of grouped packaging of finished products are described by Paine (1996), and Bureau and Multon (1996). The single packages, coming out of the filling and packaging equipment, are arranged in groups for further packaging. This is done by controlling the package flow and orientation on the belt, after leaving the single packaging line (Fig. 13.30). The single packages can be then put on cardboard trays, in cardboard boxes, or directly on pallets if the single packages are large (e.g., barrels). The filling of smaller packages in cardboard boxes is carried out as in the case of product packaging in the single cartons. Examples of further packaging in cardboard boxes are cartons with frozen products and powders; bags of pasta products, rice, etc.; and bottles. The further packing on trays is mainly done for food designated to be sold in supermarkets. The trays are wrapped for the transport, and in the supermarket, the contents of the trays are reloaded or placed on the shelf as they are. Larger quantities of grouped packages are palletized automatically. This is done either by palletizing equipment (palletizers) or robots.

13.6.2 Wrapping

Smaller quantities of products and even full pallets can be “enveloped” by wrapping with plastic film. Enveloping protects the products from mechanical damage during transport and storage; facilitates the trade, especially in connection with trade methods, such as self-service and “cash-and-carry” shopping; provides weather protection; and gives transparency to the enveloped product. For all these reasons, enveloping has grown sharply in the last years. According to Paine (1996),

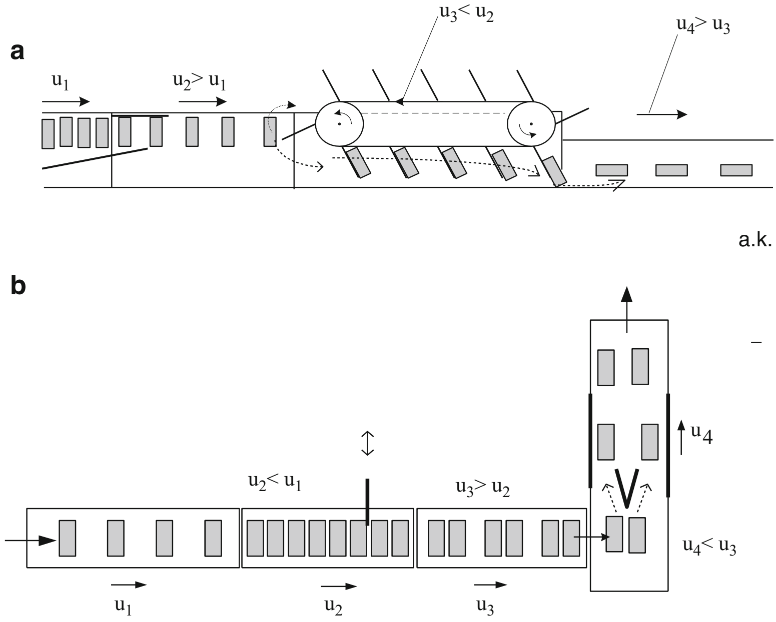


Fig. 13.30 Lining up of products (ground plan). (**a**) Further conveyance to single packages, (**b**) Further Grouped conveyance (e.g. double) of packages

enveloping can be done by one of the following methods: (a) shrink wrapping, (b) stretch wrapping, and (c) vacuum packaging.

Shrink wrapping requires a tunnel in which the grouped wrapped package is heated, e.g., by hot air. Special equipment is used for enveloping groups of few products such as fruits on trays; grouped small packages, such as drinks, small cartons, etc.; and also larger quantities on pallets. Figure 13.31 shows the shrinkage of several plastic films in relation to the temperature. Plastics, such as PVdC and rubber hydrochloride, shrink by 50 % at temperatures 150–230 °C. At temperatures higher than 250 °C, most other films shrink to more than 40 % (MPE 1975).

Figure 13.32 shows the enveloping and shrinking of small packages. The blanks, e.g., trays, are put in the magazine of the monoblock equipment. From the magazine, they are sucked and placed automatically one after the other on a conveyor belt. The grouped product is put and aligned on the horizontal blank. The forming and hot-melt gluing of the tray follows, which is done by the wraparound method. The filled tray is wrapped with plastic film. Finally, the wrapped filled tray passes through a tunnel in which the film is shrunk by heating with hot air or infrared radiation. The capacity of such machines is usually 1500–3000 trays/h. It requires about 7 kW of electrical energy (without heating). The length of a monoblock equipment (tray erection, packaging, wrapping, shrinking of film) is 6.0–7.0 m, the width is about 0.5 m, the height is 1.5–2.0 m, and the weight can be about 3 tons. Vacuum wrapping of grouped products is seldom. It is done for smaller groups of packages for weather reasons.

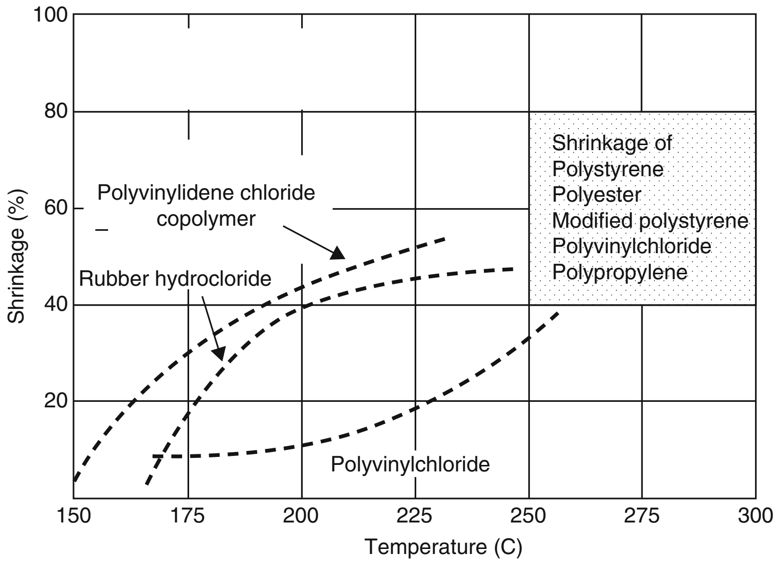


Fig. 13.31 Effect of temperature on shrinking of plastic film

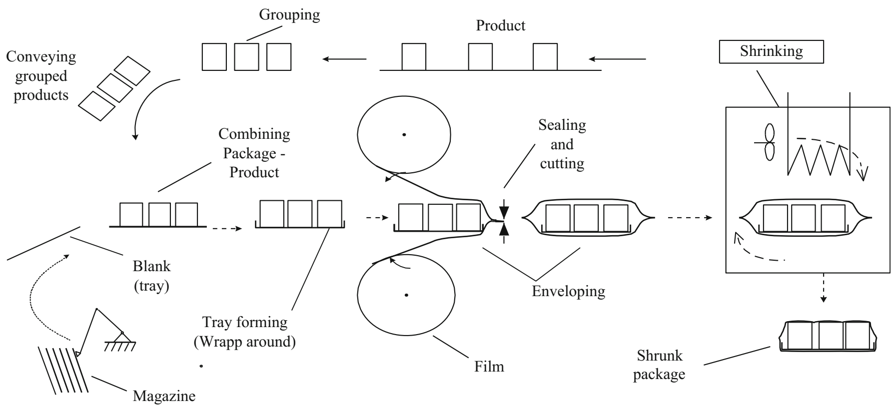


Fig. 13.32 Enveloping small packages

There are two main methods for stretch wrapping of packages with film. In the first method (Fig. 13.33a), the pallet is placed on a rotating plate. A vertical plastic film roll is placed next to the product that has to be wrapped. One end of a film sheet is fixed on the side of the stacked products, and wrapping is accomplished as the pallet rotates, pulling the film from the vertical roll. In some setups, it is possible to extend wrapping to the top of the pallet. An equipment 4.0 × 4.0 × 3.5 m can wrap about 40–50 pallets/h. The weight of such a wrapping machine is 2.0–2.5 tons and its energy consumption 4 kW. The pallet weight put on the rotating plate of such an

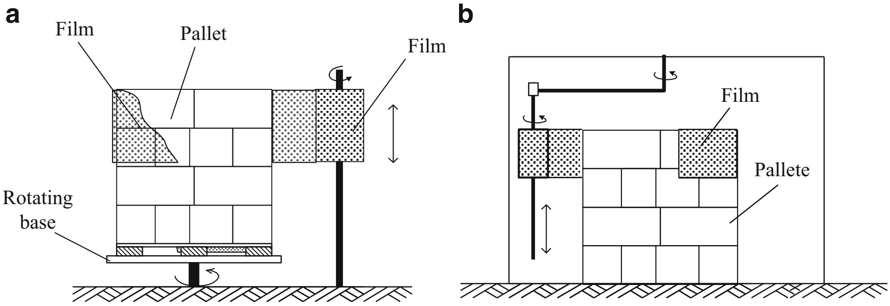


Fig. 13.33 Film-wrapping equipment. (**a**) Steady wrapping pole, (**b**) Rotating wrapping pole

equipment can be up to 4 tons. In the second method, the pallet is placed directly on the ground (Fig. 13.33b), and there is no limit on the total weight of the loaded pallet. The plastic roll is attached to a crane jib, which can move around the pallet. The capacity of this system is 40–50 pallets/h depending on load size and configuration. The unit requires up to 1 kW, and the jib can rotate around the pallet at 0–12 RPM variable speed. Indicative dimensions of such a wrapping equipment are 2.5 × 2.3 × 3.0, and the weight of the installation is about 2.5 tons.

Strapping is done in a similar way. The product that has to be strapped is placed in a ring-formed structure, which contains the wire or tape that strap the packed products around. A strapping equipment usually requires about 0.7 kW of power and has overall dimensions of 2.5 × 0.5 × 2.0 m. Its weight is 0.2 ton, and it can accept pallets or packed products of up to 1.4 m in height or width for strapping.

13.6.3 Palletizing

In palletizing, single containers (e.g., cans) or wrapped-up packages are put on pallets for facilitating the transport and storage of the products. Automatic placement of products on pallets can be made by palletizes or robots. Palletizing has been developed to one of the most important branches of materials handling, due to the expansion of trade in the last 20 years and the evolution in the logistics, including the ex-factory distribution system (e.g., the "just-in-time delivery" system). This development is also connected to the progress in computer and automation technology. The widespread introduction of the bar codes, from 1980 onward, which enable the automatic control of each delivery (Souverain 1996), has played a significant role in this development. A comprehensive description of the palletizing and the robot systems was presented by Thibault (1996). There are two main types of palletizers, the high-level (Fig. 13.34) and the low-level palletizers (Fig. 13.35). Both types consist of two sections. In the high-level palletizer, the grouped packages come to the first section, at the level of a full pallet, and they are laid on a pallet resting on an elevator plate with rolls. When the first row of the pallet is full, the

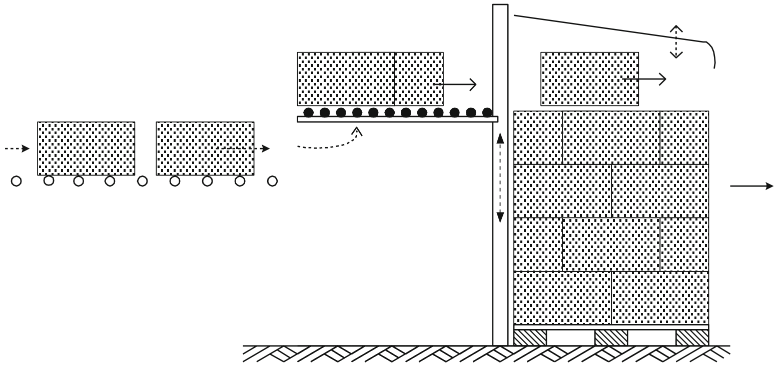


Fig. 13.34 High-level palletizer

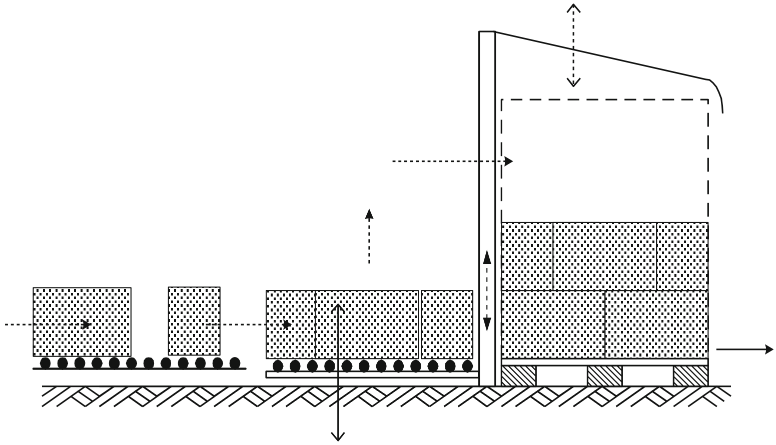


Fig. 13.35 Low-level palletizer

pallet is lowered by means of the elevator to the level of the first grouped packages' row. This procedure is repeated until a whole pallet stack is formed. The pallet stack moves/rolls subsequently to the next section, waiting for its transport to storage or to be shipped.

In the low-level palletizer (Fig. 13.35), there is a pallet-like elevator plate with rolls in the first section. An empty pallet is placed in the second part. The grouped products move on the palletizer elevator plate with rolls. When the elevator plate is one row full, it is elevated with the grouped products up to the top of the pallet of the second section of the palletizer, and it is stacked on the top of the pallet. Thereafter, the elevator returns back to be reloaded for stacking new grouped packages on those stacked just before. When a pallet pile is complete, it is carried away, e.g., by a lift truck. A palletizer may be able to load more than 10 layers/min. Its energy consumption is 9–15 kW. Usually, the plate elevator of a palletizer can carry and

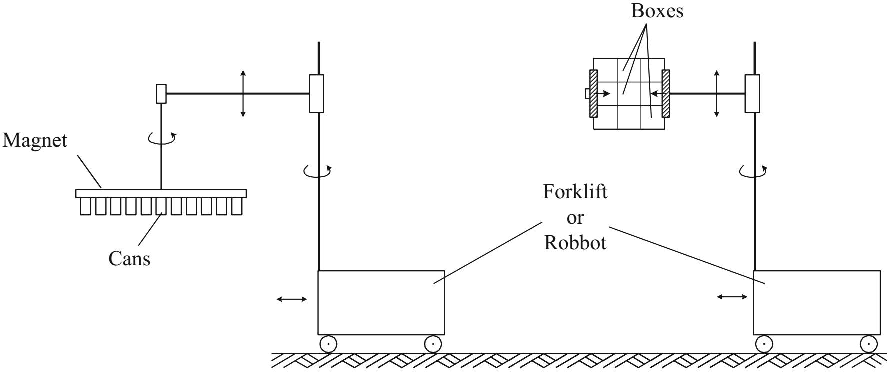


Fig. 13.36 Handling of containers

stack each time 200–250 kg. The overall dimensions of such a unit are 5.0 × 2.5 × 3.0 m and its weight is about 5 tons.

Robots can be also used in palletizing. They have the advantage of flexibility and work under unfavorable conditions. Palletizers and robots can be also used in putting products in larger containers (e.g., boxes, box pallets). In this case, the containers are raised, and when they are exactly above the their final destination, they are gently moved down. According to Swientek (1993), the food manufacturers are the biggest users of robots in palletizing in Japan. The holding of containers can be done in several ways. Cans can be held by magnetic force. Boxes can be held by bracket holders or suction (Fig. 13.36). Almost all equipment used in palletizing can be also used in de-palletizing.

13.7 Cleaning of Packaging Media

The food containers are cleaned before putting products in it. For relatively short time storage of solid food such as fruits and vegetables, usually plastic or wooden boxes or containers are used. The containers (boxes) that are filled with fruits such as apples and peaches can carry about 20 kg/box. The smaller ones usually containing "one row" of fruits carry 3–5 kg of products. Bags and sacks are used for small piece, grain, and ground-products (Chap. 3). Liquids or liquid-containing products are packed in glass, plastic, or metal containers.

The containers (usually plastic containers for products of about 20 kg) used to transport and store fruits and vegetables with short-time cold storage, before filling them in fields, are cleaned up passing continuously through tunnels in which they are washed out by pressurized water and steam. The recycled bottles and jars are cleaned in installations such as the indicated in Fig. 13.37.

One possibility is to soak the containers firstly in baths containing adequate warm detergent whose quality depends on the type and the spoil condition of the

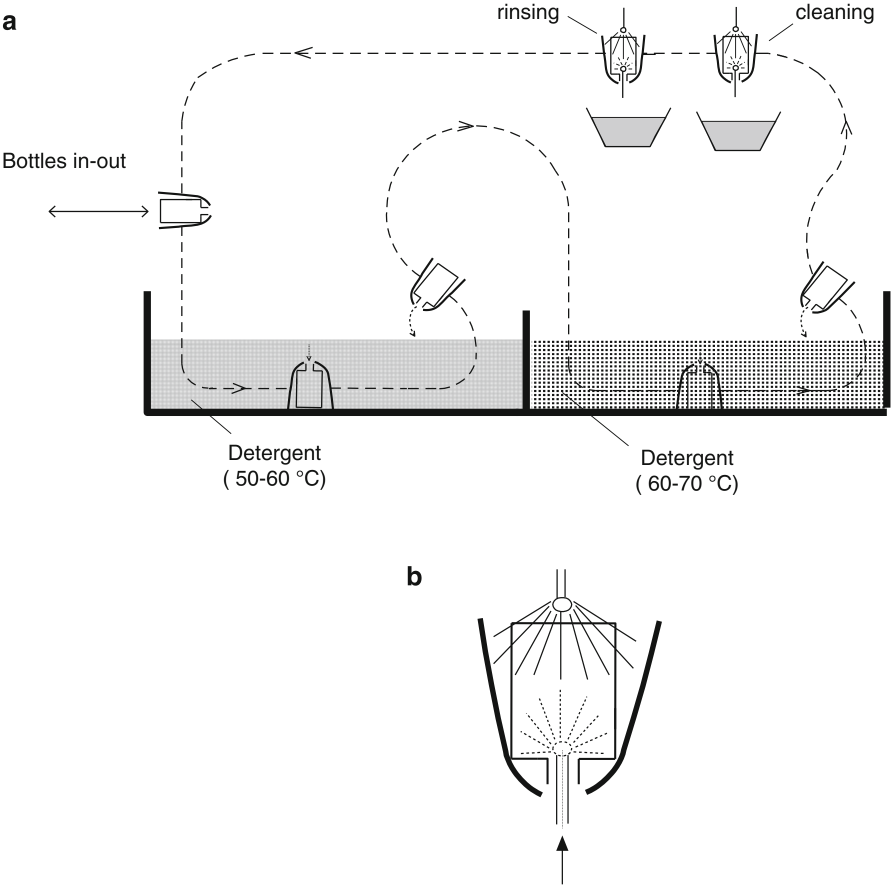


Fig. 13.37 Cleaning of bottles. (**a**) Processing line, (**b**) Rinsing of bottles

containers. Those emptied from detergent containers are successively guided in a second bath containing hotter detergent. The containers are then sprayed internally and externally by a 3–4 % NaOH solution and rinsed out by pressurized water. The glass containers are kept up to 90 °C during the cleaning process, but gradually for avoiding thermal stress, this temperature is reduced to the environment temperature.

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