8 Paper and Paperboard Packaging

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8.1 INTRODUCTION

A wide range of paper and paperboard is used in packaging today – from lightweight infusible tissues for tea and coffee bags to heavy duty boards used in distribution. Paper and paperboard are found wherever products are produced, distributed, marketed and used, and account for about one-third of the total packaging market. Over 40% of all paper and paperboard consumption in Europe is used for packaging and over 50% of the paper and paperboard used for packaging is used by the food industry.

One of the earliest references to the use of paper for packaging food products is a patent taken out by Charles Hildeyerd on 16 February 1665 for 'The way and art of making blew paper used by sugar-bakers and others' (Hills, 1988).

The use of paper and paperboard for packaging purposes accelerated during the latter part of the nineteenth century to meet the needs of manufacturing industry. The manufacture of paper had progressed from a laborious manual operation, one sheet at a time, to continuous high speed production with wood pulp replacing rags as the main raw material. There were also developments in the techniques for printing and converting these materials into packaging containers.

Today, examples of the use of paper and paperboard packaging for food can be found in many places, such as supermarkets, traditional markets and retail stores, mail order, fast food, dispensing machines, pharmacies, and in hospital, catering and leisure situations.

Uses can be found in packaging all the main categories of food, such as:

- dry food products – cereals, biscuits, bread and baked products, tea, coffee, sugar, flour, dry food mixes, etc
- frozen foods, chilled foods and ice cream
- liquid foods and beverages – juice drinks, milk and milk derived products
- chocolate and sugar confectionery
- fast foods
- fresh produce – fruit, vegetables, meat and fish

Packaging made from paper and paperboard is found at the point of sale (primary packs), in storage and for distribution (secondary packaging).

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Paper and paperboard are sheet materials made up from an interlaced network of cellulose fibres. These materials are printable and have physical properties that enable them to be made into flexible and rigid packaging by cutting, creasing, folding, forming, gluing, etc. There are many different types of paper and paperboard. They vary in appearance, strength and many other properties depending on the type(s) and amount of fibre used and how the fibres are processed in paper and paperboard manufacture.

The amount of fibre is expressed by the weight per unit area (grams per square metre, g/m^2, or lbs per 1000 sq ft), thickness (microns, μm or 0.001 mm, and thou (0.001 inch), also referred to as *points*) and appearance (colour and surface finish).

Paperboard is thicker than paper and has a higher weight per unit area. Paper over 200 g/m^2 is defined by ISO (International Organisation for Standardization) as paperboard or board. However, some products are known as paperboard even though they are manufactured in grammages less than 200 g/m^2.

Papers and paperboards used for packaging range from thin tissues to thick boards. The main examples of paper- and paperboard-based packaging are:

- paper bags, wrapping, packaging papers and infusible tissues, e.g. tea and coffee bags, sachets, pouches, overwrapping paper, sugar and flour bags, carrier bags
- multiwall paper sacks
- folding cartons and rigid boxes
- corrugated and solid fibreboard boxes (shipping cases)
- paper-based tubes, tubs and composite containers
- fibre drums
- liquid packaging
- moulded pulp containers
- labels
- sealing tapes
- cushioning materials
- cap liners (sealing wads) and diaphragms (membranes)

Paper and paperboard packaging is used over a wide temperature range, from frozen food storage to the high temperatures of boiling water and heating in microwave and conventional radiant heat ovens.

Whilst it is approved for direct contact with many food products, packaging made solely from paper and paperboard is permeable to water, water vapour, aqueous solutions and emulsions, organic solvents, fatty substances (except grease resistant paper grades), gases, such as oxygen, carbon dioxide and nitrogen, aggressive chemicals and to volatile flavours and aromas. Whilst it can be sealed with several types of adhesive, it is not itself heat sealable.

Paper and paperboard, however, can acquire barrier properties and extended functional performance, such as heat sealability for leak-proof liquid packaging, through coating and lamination with plastics, such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET or PETE) and ethylene vinyl alcohol (EVOH), and with aluminium foil, wax, and other treatments. Packaging made solely from paperboard can provide a wide range of barrier properties by being overwrapped with a heat sealable film, such as polyvinylidene chloride (PVdC) coated-oriented polypropylene (OPP or BOPP) or a similarly coated regenerated cellulose film.

8.2 PAPER AND PAPERBOARD – FIBRE SOURCES AND FIBRE SEPARATION (PULPING)

Paper and paperboard are sheet materials comprising an interlaced network of cellulose fibres derived from wood. Cellulose fibres are capable of developing physico-chemical bonds at their points of contact within the fibre network, thus forming a sheet. The strength of the sheet depends on the origin and type of fibre, how the fibre has been processed, the weight per unit area, and thickness.

The type of fibre also influences the colour. Most paperboards have a multilayered construction that provides specific performance advantages and gives the manufacturer flexibility of choice, depending on the packaging end use, of the type of fibre used in the individual layers. Virgin, or primary, fibre is derived directly from wood by a process known as pulping. This can be done mechanically (Fig. 8.1) or with the help of chemicals that dissolve most of the non-cellulose components of the wood, which are subsequently used to provide energy (Fig. 8.2).

The terms sulphate and sulphite refer to the chemical processes used to separate the fibres from wood, sulphate being the more dominant process today. Mechanically separated fibre retains the colour of the wood though this can be made lighter by mild chemical treatment. Chemically separated fibre is brown but it can be bleached to remove all traces of non-cellulosic material. Pure cellulose fibres are translucent individually but appear white when bulked together (Fig. 8.2).

Fibre recovered (secondary fibre) from waste paper and board, which is not de-inked and bleached, is grey or brown. Fibre recovered from brown packaging will be brown in colour. When mixed printed waste recovered paper and board is processed the colour of the pulp is grey. Pulp can be dyed during processing to meet a specific colour specification. The process whereby recovered fibre is made into paper and paperboard is an example of material recycling (Fig. 8.3).

Fibres can withstand multiple recycling but the process of recycling reduces fibre length and inter-fibre bonding, features related to sheet strength properties. Furthermore, it must also be appreciated that some papers and boards cannot be recovered by nature of their use and, hence, there is a constant need for virgin fibre to maintain the amount and strength of fibres. In practice, the proportion of fibre that is recovered and recycled in various countries is between

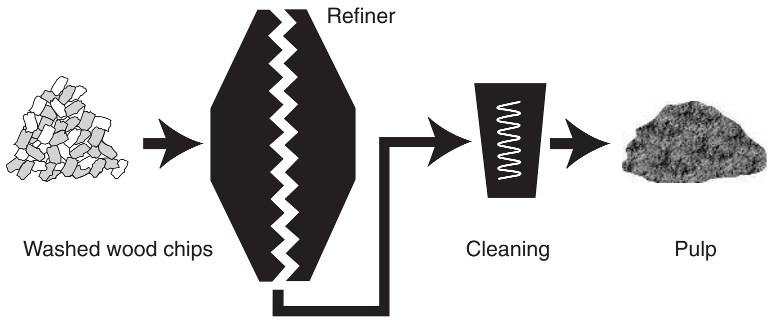

Fig. 8.1 Production of mechanical pulp. (Courtesy of Pro Carton.)

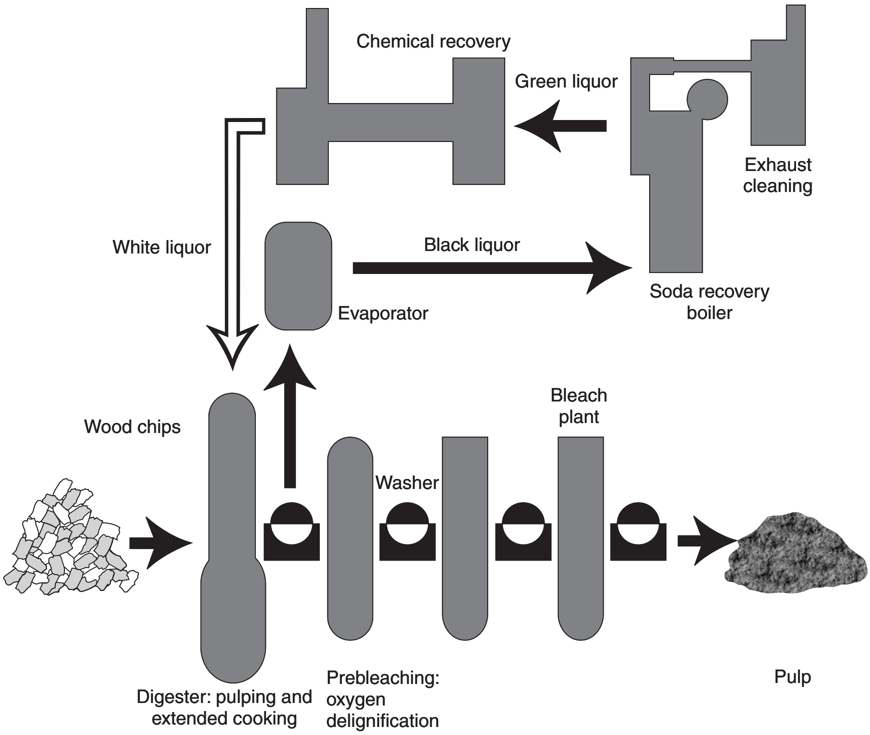

Fig. 8.2 Production of chemical pulp. (Courtesy of Pro Carton.)

40 and 60%. Another important factor relevant to sheet properties is the species of tree from which the fibres are derived. In general terms, the industry uses long fibres for strength and short fibres for surface smoothness and efficient sheet forming in manufacture. Long fibres are derived from coniferous softwoods, such as Spruce, Pine and Douglas Fir, and have average lengths of 3–4.5 mm. Short fibres, such as those derived from Birch, have average lengths of 1–1.5 mm.

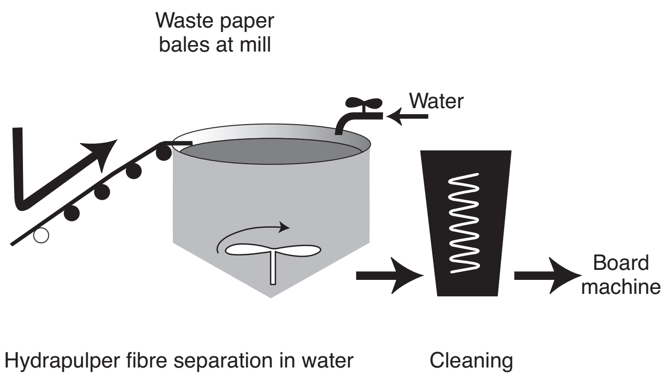

Fig. 8.3 Production of recycled pulp. (Courtesy of Pro Carton.)

8.3 PAPER AND PAPERBOARD MANUFACTURE

8.3.1 Stock preparation

If pulp is bought in bales, it is first dispersed in water in a hydrapulper. All pulp, including pulp that comes straight from the pulpmill without drying, is then treated in various ways to prepare it for use on the paper or paperboard machine. Inter-fibre bonding can be increased by mechanical refining, in which the surface structure of the fibre is modified by swelling the fibre in water and increasing the surface area. The degree of refining, which also influences the drainage rate at the next stage in manufacture, is adjusted to suit the properties of the intended paper or paperboard product.

Additives, such as alum or synthetic resins, are used to increase the water repellancy of the fibres. Wet strength resins can be added to increase the strength of the product when saturated with water. Fluorescent whitening agents (FWAs), also known as optical brightening agents (OBAs), can be added at this stage to increase whiteness and brightness.

8.3.2 Sheet forming

The fibre in water suspension, roughly 2% fibre and 98% water, is *formed* in an even layer. This is achieved by depositing the suspension of fibre at a constant rate onto a moving plastic mesh, known as the wire (Fig. 8.4). On some machines, forming is carried out on a wire mesh covered cylinder. Forming results in a layer of entangled fibres from which water is then removed by drainage, which may be assisted by vacuum. Tissue, paper, and thin boards can be formed in one layer. Thicker and heavier higher grammage paperboards require several layers of pulp, either the same type, or different pulps, depending on the board type, being brought together successively in the wet state.

Forming on a wire mesh in this way has two important consequences. Firstly, there is a slight difference in appearance between the wire side of the sheet and the other side (top side). This effect is eliminated if the sheet is subsequently coated with a white mineral (china clay) coating, or if a specific type of twin wire former is used where both outer sides of the sheet are in contact with identical wire mesh surfaces. Secondly, the method of forming influences the orientation

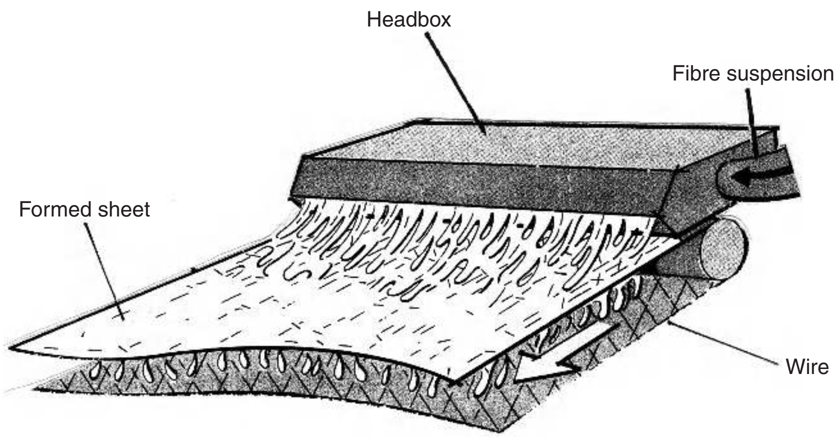

Fig. 8.4 Simplified diagram of the forming process. (Courtesy of Iggesund Paperboard.)

of the fibres in the sheet. Since fibres are long and thin, they tend to line up in the direction of motion on the machine. This is called the machine direction (MD). Strength properties, such as tensile and stiffness, are higher in the MD. One of the aims of successful forming is to randomise the orientation of fibres in the sheet. Nevertheless, the orientation occurs and it is normal to measure strength properties both in the MD and in the direction at right angles to the MD, known as the cross direction (CD). The fibres form an entangled network that is assisted by creating turbulence in the headbox immediately prior to forming and, on some paper machines, by shaking the wire from side to side.

8.3.3 Pressing

At the end of the forming section, or wet end of the machine, the sheet is sufficiently consolidated by the removal of water to support its own weight to transfer into the press section (Fig. 8.5). Here it is held between absorbent blankets and gently pressed using steel rolls so that with vacuum assistance more water is removed, reducing the moisture content to about 60–65%.

8.3.4 Drying

The moisture is reduced to less than 10%, depending on grade, by passing the sheet over steam heated cylinders. Some machines include in their drying section a very large heated cylinder with a polished steel surface. This is an MG (machine glazing) cylinder – also known as a

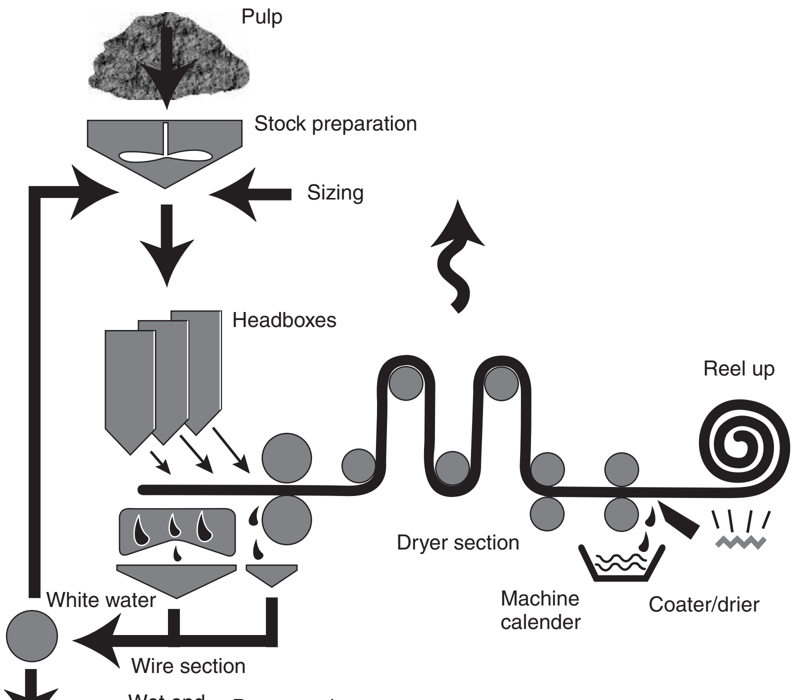

Fig. 8.5 Principal features in manufacture of paper/paperboard – the number of headboxes will vary depending on the product. (Courtesy of Pro Carton.)

Yankee cylinder. Paper can be produced with a glazed surface on one side and on some board machines the MG cylinder is used to produce a smooth surface, whilst preserving thickness, thereby giving higher stiffness for a given grammage. A starch solution is sometimes applied towards the end of the drying section to one or both sides of the sheet. This is known as surface sizing. It improves the strength and finish of the sheet and anchors the fibres firmly in the sheet. Squeezing the sheet through a series of steel/composition rolls can enhance smoothness and thickness uniformity. This is known as calendering. Paper may be calendered at high speed in a separate process, known as supercalendering.

8.3.5 Coating

White pigmented coatings are applied to one or both sides of many types of paper and board on-machine. The coatings comprise mineral pigments, such as china clay and calcium carbonate, and synthetic binders (adhesives), dispersed in water. Excess coating is usually applied, it is smoothed and the excess removed. A number of techniques may be used – metering bar, air knife or blade coating.

One, two or three layers of coating may be applied. Coatings are dried by radiant heat and by passing the sheet over steam heated drying cylinders. They may be burnished (polished) depending on the required appearance, colour, smoothness, gloss and printing properties. Coatings can be applied off-line. In the cast coating process, the smooth wet coating is cast against a highly polished chromium-plated heated cylinder. When dry, the coating separates from the metal surface leaving the coating with high smoothness and gloss.

8.3.6 Reel-up

Finally, the paper or board is reeled up prior to *finishing*.

8.3.7 Finishing

The large diameter, full machine width reels of paper and board are then slit into narrower reels of the same or smaller diameter or cut into sheets to meet customer and market needs. Sheets may be guillotined, pile turned, counted, ream wrapped, palletised, labelled and wrapped securely, usually with moisture resistant material, such as PE coated paper or PE film.

8.4 PACKAGING PAPERS AND PAPERBOARDS

A wide range of papers and paperboards are commercially available to meet market needs resulting from the choice of fibres available, bleached and unbleached, virgin and recycled, and because fibres can be modified at the stock preparation stage.

Paper and board-based products can be made in a wide range of grammages and thicknesses. The surface finish (appearance) can be varied mechanically. Additives introduced at the stock preparation stage provide special properties.

Coatings applied, smoothed and dried, to either one or both surfaces, offer a variety of appearance and performance features that are enhanced by subsequent printing and conversion, thereby resulting in various types of packaging.

To illustrate these features of paper and paperboard, some examples are described below.

8.4.1 Wet strength paper

Paper sacks used in wet conditions need to retain at least 30% of their dry strength when saturated with water. To achieve wet strength, urea formaldehyde and melamine formaldehyde are added to the stock. These chemicals cross-link during drying and are deposited on the surface of the cellulose fibres making them resistant to water absorption.

8.4.2 Microcreping

Microcreping, e.g. as achieved by the Clupak process, builds an almost invisible crimp into paper during drying enabling paper to stretch up to 7% in the MD compared to a more normal 2%. When used in paper sacks this feature improves the ability of the paper to withstand dynamic stresses, such as occur when sacks are dropped.

8.4.3 Greaseproof

The hydration (refining) of fibres at the stock preparation stage, already described, is taken much further than normal. It is carried out as a batch process and is known as *beating*. The fibres are treated (hydrated) so that they become almost gelatinous.

8.4.4 Glassine

This is a supercalendered (SC) greaseproof paper. The calendering produces a very dense sheet with a high (smooth and glossy) finish. It is non-porous, greaseproof, can be laminated to board and can be silicone coated to facilitate product release. Glassine is also available in several colours.

8.4.5 Vegetable parchment

Bleached chemical pulp is made into paper conventionally and then passed through a bath of sulphuric acid. Some of the surface cellulose is gelatinised on passing into water and redeposited between the surface fibres forming an impervious layer. This paper has high grease resistance and wet strength.

8.4.6 Tissues

Neutral pH grades with low chloride and sulphate residues are laminated to aluminium foil. The grammages range from 17 to 30 g/m^2. Tea and coffee bag tissue is a special light weight tissue available either as a heat sealable product (containing a proportion of polypropylene fibres), or as a non-heat sealable product, in grammages from 12 to 17 g/m^2. It incorporates long fibres, such as those derived from manilla hemp, which give a strong permeable sheet at the low grammages used.

A 100% biodegradable and compostable tea and coffee bag tissue is now available with fibre based on Ingeo^{TM} (PLA, polylactic acid). This product is suitable for use on tea and coffee, packing machines that use ultrasonic sealing technology (Ahlstrom, 2009).

8.4.7 Paper labels

These may be MG (machine glazed), MF (machine finished) or calendered kraft papers (100% sulphate chemical pulp) in the grammage range 70–90 g/m^2. The paper may be coated on-machine or cast coated for the highest gloss in an off-machine or secondary process.

The term *finish* in the paper industry refers to the *surface* appearance. This may be:

- MF – machine finish, smooth but not glazed
- WF – water finish where one or both sides are dampened and smoothed, to be smoother and glossier than MF
- MG – machine glazed with high gloss on one side only
- SC – supercalendered, i.e. dampened and polished off-machine to produce a high gloss on both sides

8.4.8 Bag papers

For sugar or flour, coated or uncoated bleached kraft in the range 90–100 g/m^2 is used. Imitation kraft is a term on which there is no universally agreed definition, it can be either a blend of kraft with recycled fibre or it can be 100% recycled. It is usually dyed brown. It has many uses for wrapping and for bags where it may have an MG and a ribbed finish. Thinner grades may be used for lamination with aluminium foil and PE for use on form/fill/seal machines.

8.4.9 Sack kraft

Usually, this is unbleached kraft (100% sulphate chemical) pulp, though there is some use of bleached kraft. The grammage range is 70–100 g/m^2.

8.4.10 Impregnated papers

Wax impregnated paper and fluorocarbon treatment for grease/fat resistance is produced on-machine.

8.4.11 Laminating papers

These are coated and uncoated papers (40–80 g/m^2) based on both kraft (sulphate) and sulphite pulps. These papers can be laminated to aluminium foil and extrusion coated with PE. The heavier weights can be PE laminated to plastic films and wax or glue laminated to unlined chipboard.

8.4.12 Solid bleached board (SBB)

Solid bleached board is made exclusively from bleached chemical pulp (Fig. 8.6). It usually has a mineral pigment coated top surface and some grades are also coated on the back. The term SBS (solid bleached sulphate), derived from the method of pulp production, is sometimes used to describe this product.

This paperboard has excellent surface and printing characteristics. It gives wide scope for innovative structural design and can be embossed, cut, creased, folded and glued with ease. This

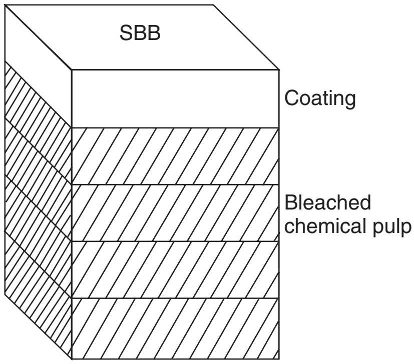

Fig. 8.6 Solid bleached board. (Courtesy of Iggesund Paperboard.)

is a pure cellulose primary (virgin) paperboard with consistent purity for food product safety, making it the best choice for the packaging of aroma and flavour sensitive products. Examples of use include chocolate confectionery, frozen foods, cheese, tea, coffee, reheatable products and as a base for liquid packaging.

8.4.13 Solid unbleached board (SUB)

Solid unbleached board is made exclusively from unbleached chemical pulp (Fig. 8.7). The base board is brown in colour. This product is also known as solid unbleached sulphate. To achieve a white surface, it can be coated with a white mineral pigment coating, sometimes in combination with a layer of bleached white fibres under the coating. This board is used where there is a high strength requirement in terms of puncture and tear resistance and/or good wet strength is required, such as for bottle or can multipacks, and as a base for liquid packaging.

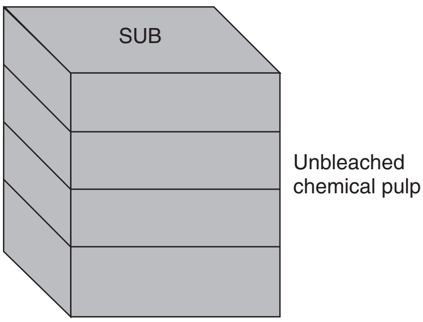

Fig. 8.7 Solid unbleached board (courtesy of Iggesund Paperboard).

8.4.14 Folding boxboard (FBB)

Folding boxboard comprises middle layers of mechanical pulp sandwiched between layers of bleached chemical pulp (Fig. 8.8). The top layer of bleached chemical pulp is usually coated with a white mineral pigment coating. The back is cream (manilla) in colour. This is because the back layer of bleached chemical pulp is translucent allowing the colour of the middle layers to show through. However, if the mechanical pulp in the middle layers has been given a mild

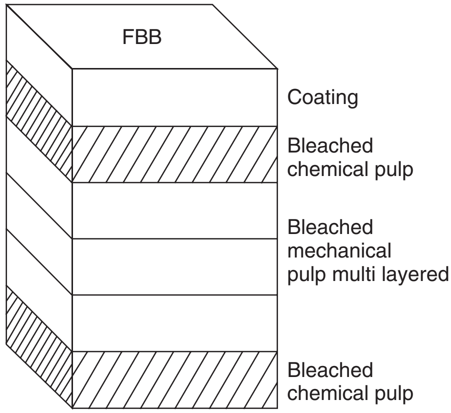

Fig. 8.8 Folding boxboard (courtesy of Iggesund Paperboard).

chemical treatment (bleached), it is lighter in colour, and this makes the reverse side colour lighter in shade. The back layer may, however, be thicker or coated with a white mineral pigment coating, thus becoming a white back folding box board. The combination of inner layers of mechanical pulp and outer layers of bleached chemical pulp creates a board with high stiffness.

Fully coated grades have a smooth surface and excellent printing characteristics. This paperboard is a primary (virgin fibre) product with consistent purity for food product safety and suitable for the packing of aroma and flavour sensitive products. It is widely used for food products, such as confectionery, frozen and chilled foods, tea, coffee, bakery products and biscuits.

8.4.15 White lined chipboard (WLC)

White lined chipboard comprises middle plies of recycled pulp recovered from mixed papers or carton waste. The middle layers are grey in colour. The top layer, or liner of bleached chemical pulp is usually white mineral pigment coated. The second layer, or under liner, may also comprise bleached chemical pulp or mechanical pulp. This product is also known as newsboard. The term chipboard is also used, though this name is more likely to be associated with an unlined grade, i.e. without a white, or other colour, surface liner ply (Fig. 8.9).

The reverse-side outer layer usually comprises specially selected recycled pulp and is grey in colour. The external appearance may be white by the use of bleached chemical pulp and, possibly, a white mineral pigment coating. (White PE has also been used.) There are additional grades of unlined chipboard and grades with special dyed liner plies for use in the manufacture of corrugated fibreboard.

The overall content of WLC varies from about 80–100% recovered fibre depending on the choice of fibre used in the various layers. WLC is widely used for cereals, dried foods, frozen and chilled foods, and confectionery outers.

8.5 PROPERTIES OF PAPER AND PAPERBOARD

The features of paper and paperboard that make these materials suitable for packaging relate to appearance and performance. These features are determined by the type of paper and paperboard – the raw materials used and the way they have been processed. Appearance and

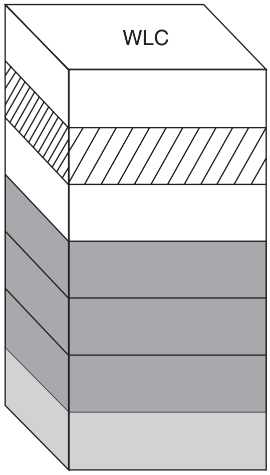

Fig. 8.9 White lined chipboard (courtesy of Iggesund Paperboard).

performance can be related to measurable properties that are controlled in the selection of raw materials and the manufacturing process.

National and international standard test procedures have been published by British Standards (UK), DIN (Germany), ISO, and in the United States, there is TAPPI (Technical Association for the Pulp and Paper Industry) and ASTM International (formally the American Society for Testing Materials).

8.5.1 Appearance

Appearance relates to the visual impact of the pack and can be expressed in terms of colour, smoothness and whether the surface has a high or low gloss (matte) finish.

Colour depends on the choice of fibre for the outer surface, and also, where appropriate, the reverse side. As described above, the choice is either white, brown or grey. In addition, some liners for corrugated board comprise a mix of bleached and brown fibres.

Other colours are technically possible either by using fibres dyed to a specific colour or coated with a mineral pigment-coloured coating. Where paper and paperboard is required for quality printing, it is usually coated on the print side during manufacture with a mineral-based coating, usually white in colour, based on china clay or calcium carbonate. The reverse side may also be coated where two-side printing is required.

8.5.2 Performance

Performance properties are related to the level of efficiency achieved during the manufacture of the pack, in printing, cutting and creasing, gluing and the packing operation. Performance properties are also related to pack compression strength in storage, distribution, at the point of sale and in consumer use.

Specific measurable properties include stiffness, short span compression (rigidity) strength, tensile strength, wet strength, % stretch, tear strength, fold endurance, puncture resistance and ply bond strength. Other performance properties relate to moisture content, air permeability, water absorbency, surface friction, surface tension, ink absorbency, etc. Chemical properties include pH, whilst chloride and sulphate residues are relevant for aluminium foil lamination.

Flatness is easily evaluated but is a complicated issue as lack of flatness can arise from several potential causes, from the hygrosensitivity characteristics of the fibre, manufacturing variables and handling at any stage, including printing and use. Neutrality with respect to odour and taint, and product safety are performance needs that are important in the context of paper and board packaging, which is in direct or close proximity to food.

8.6 ADDITIONAL FUNCTIONAL PROPERTIES OF PAPER AND PAPERBOARD

Additional barrier and functional performance for food packaging needs can be imparted to paper and paperboard by one or more of the following processes.

8.6.1 Treatment during manufacture

8.6.1.1 *Hard sizing*

Sizing is a term used to describe a treatment that delays the rate at which water is absorbed, both through the edges (wicking) and through the surface. It is achieved by the use of chemicals added during the stock, or pulp, preparation stage prior to forming in manufacture. This is known as *internal sizing*. Traditionally, alum, a natural resin, derived from wood was used. Today several synthetic sizing materials are also available. Paperboard used in packaging for frozen and chilled food and for liquid packaging needs to be hard sized.

8.6.1.2 *Sizing with wax*

Sizing with wax on-machine.

8.6.1.3 *Acrylic resin dispersion*

Acrylic resin dispersion (water-based) coating – heat sealable, moderate moisture and oxygen barrier, available as one side coating on-machine.

8.6.1.4 *Fluorocarbon dispersion*

Fluorocarbon dispersion coating, high fat resistant one-side coating on-machine.

Note: The terms *on-machine* and *off-machine* are commonly used in the paper industry. The machine in question is the paper or paperboard machine. An on-machine process takes place as the paper or paperboard is being made and off-machine is a subsequent process carried out on a machine designed specially for the process concerned.

8.6.2 Lamination

This process applies another functional or decorative material, in sheet or reel form, to the paper or paperboard surface with the help of an adhesive. Examples are:

- aluminium foil applied to one or both sides, provides a barrier to moisture, flavour, common gases, such as oxygen, and UV light. Aluminium foil laminated to paper and paperboard is also used for direct contact and easy release for foods that will be cooked or reheated in radiation or convection ovens. Aluminium foil is also used to provide a decorative metallic finish as, for example, on cartons for chocolate confectionery

- greaseproof paper laminated to paperboard: good grease resistance for fat containing products, temperature resistance to 180°C for cooking/reheatable packs. If additionally the greaseproof paper has a release coating, this product can be used to pack sticky or tacky products
- glassine paper laminated to paperboard: grease resistance for products with moderate fat content, such as cakes or bake-in-box applications. If the glassine is coloured the pack should not be used in reheatable applications but food contact approved grades can be used for direct contact with, for example, chocolate

The adhesives used for lamination include PVA-type emulsions, starch-based, resin/solvent-based, cross-linking compounds, molten wax or PE depending on the needs of the particular laminate. The presence of wax and PE also improves the barrier to water vapour. When PE is used as an adhesive the process would be described as *extrusion lamination*.

8.6.3 Plastic extrusion coating and laminating

Polyethylene (PE) heat sealable moisture barrier. Low density polyethylene (LDPE) is widely used in the plastic extrusion coating and laminating of paper and paperboard. Easier heat sealing results when PE is modified with EVA (Ethylene vinyl acetate). Medium and high density PE has a higher temperature limit, better abrasion resistance and higher barrier properties than LDPE. One and two side coatings are available (Fig. 8.10).

Polypropylene (PP) heat sealable, moisture and fat barrier. It can withstand temperatures up to 140°C and is used for packing foods to be reheated in ovens up to this temperature. One and two side coatings are available.

Polyethylene terephthalate (PET) heat sealable, moisture and fat barrier. It can withstand temperatures up to 200°C and is dual ovenable (microwave and conventional ovens). It is coated only on the non-printing side.

Polymethylpentene (PMP) moisture and fat barrier and not heat sealable. It is, therefore, used as flat sheets, deep drawn trays and trays with mechanically locked corners. It is coated only on the non-printing side.

Ethylene vinyl alcohol (EVOH) and polyamide (PA) heat sealable, fat, oxygen and light barrier. EVOH is moisture sensitive and needs to be sandwiched between hydrophobic materials, such as PE. It can be used as a non-metallic alternative to the aluminium foil layer.

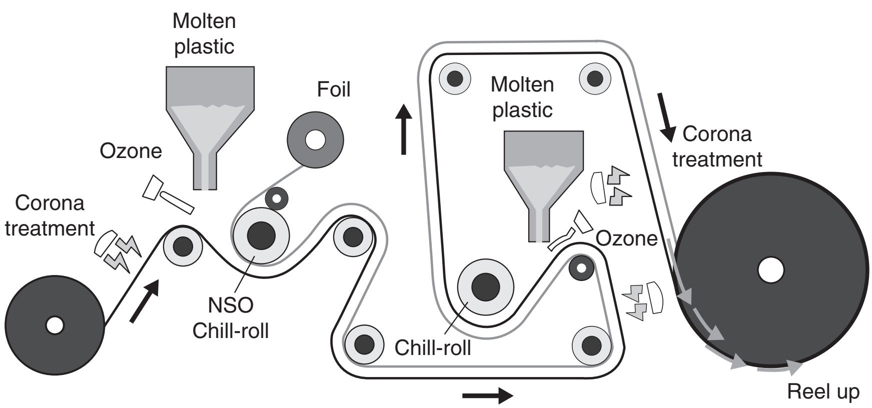

Fig. 8.10 The extrusion and extrusion laminating process. (Courtesy of Iggesund Paperboard.)

Ionomer resin (Surlyn®), a polyolefin with high resistance to fat, including essential oils in citrus fruit, and moisture with very good sealing properties, is used as a *tie* layer on aluminium foil when applying PE to foil.

Bioplastic extrusion coatings are now available as a PE alternative. This starch-based material is sustainable and meets the EN13432 standard for compostability (Packaging News 2008).

The process of extrusion is often extended to include extrusion lamination so that a structure, such as paper or paperboard/PE/aluminium foil/PE, can be produced in one operation on an extruder with two extruding units.

Note: By special selection of polymers, e.g. for lids and trays, it is possible to provide easy-open peelable heat-seals.

8.6.4 Printing and varnishing

Usually, printing and varnishing are associated with the appearance of the pack with respect to the visual impact of the pack through colour, information, text and illustration. There are also important functional aspects of printing and varnishing that are important for food packaging.

All the main printing processes are used – gravure, flexographic, letterpress, silk screen and lithographic. Paper and paperboard can also be printed by the recently introduced digital process. Choice is influenced by the appearance and performance (functional) needs and commercial aspects, such as order size, lead time and price.

The inks and varnishes may be those described as traditional for the process concerned, based on pigment, resin and vehicle. The vehicle, which transports the pigment and resin from the ink or varnish reservoir to the substrate via the printing plate, varnish pick-up roll, etc., may be an organic solvent, water or a drying oil. For some processes, pigments are replaced by dyes. In recent years, inks and varnishes cured by UV radiation have also become popular, and these materials are extremely inert. They give good rub resistance in wet and dry conditions and are resistant to product absorption. The inks contain pigment, cross-linking resins and a photo-initiator; they are 100% solid and are dry immediately after printing.

The functional requirements include adherence to colour standards, light fastness, rub resistance, print-to-print and print-to-pack registration and stability within the conditions of use. For some food products where the print is in close proximity to the food, e.g. chocolate confectionery, it is important that no residual solvents from the inks and varnishes, or any other interaction between print and product affects the food product.

8.6.5 Post-printing roller varnishing/coating/laminating

Post-printing roller varnishing and coating is usually associated with high gloss and can involve UV cured varnishes. The process can also be used for the application of functional varnishes to meet specific end use needs. The most common example of this is the application of heat-seal coatings for blister packs.

Another example of coating is the application of wax. This can take a variety of forms:

- dry waxing where molten wax is applied to one or both sides of a printed paper or a printed/cut/creased carton blank. The appearance is a matte finish
- wet or high gloss waxing. Immediately after coating, the printed paper or carton blank is conveyed through very cold water. This causes the wax to set immediately, producing a very high gloss finish

Waxed paperboard provides water and water vapour resistance. It can be heat sealable. The first liquid packaging cartons (~1920) were waxed. Wax is also a good gas barrier and can therefore protect food products against flavour loss or ingress of contamination. The main food applications today are for bread wrap, items of sugar confectionery (paper), frozen food and ice cream (cartons) and fresh produce (corrugated board). Cellulose acetate and OPP laminated to paperboard enhance appearance after printing.

8.7 DESIGN FOR PAPER AND PAPERBOARD PACKAGING

Surface design concerns colour, text, illustrations, decoration, finish (gloss or matte) and surface texture. It is achieved by making use of the basic surface properties of the paper or paperboard and through lamination, coating, hot foil stamping, embossing, printing and varnishing. Surface design usually refers to the external surface of a pack but there are situations where the internal surface is important for the overall effect, e.g. the inside surfaces of chocolate and tea bag cartons.

Structural design is concerned with the shape of packages. The functional shape is determined by the needs of the pack, e.g. closure and opening features. Creative shape adds interest for promotional needs where that is appropriate. Paper and paperboard are materials that give a designer freedom to develop imaginative solutions in meeting customer needs. This is due to a number of factors:

- range of surfaces, in terms of colour and finish, available
- range of strength properties, in terms of fibre type, thickness and method of manufacture, available
- choice of functional coating, lamination, decoration, printing, etc
- ease of conversion into packages in terms of cutting, creasing, folding, gluing, locking, heat sealing, etc
- innovative machinery for conversion and packing

8.8 PACKAGE TYPES

8.8.1 Tea and coffee bags

These are made from very light-weight porous tissues. There are heat-sealed bags where the fibre structure (grammage ~17 g/m^2) contains a heat sealable fibre, such as PP. Bags may be flat, square, four side perimeter sealed, or they may be round or pyramidal in shape. Another design is folded and stapled giving a larger surface area for infusion and using a lighter weight tissue (~12 g/m^2). All these bags are closely associated with the machinery that forms, fills and seals the bags – both types may have strings and tags. It is possible to link such machines with enveloping machines that can comprise paper, or paper laminated or coated, with moisture and gas barrier properties. Tea and coffee bag packing machines can include, or be linked to, cartonning or bagging machines.

8.8.2 Paper bags and wrapping paper

The paper bag is the traditional type of packaging where the product is packed at the point of sale, typically, in stores and markets where fruit and vegetables are sold and in bakeries for fresh bread and cakes. Manual wrapping using precut sheets is also widely used, e.g. in butchers shops and for fish and chips. The paper-based carrier bag with handles of various types is used for assorted items in retail shopping, and for luxury items and gifts where paper-based decorative finishes are used.

8.8.3 Sachets/pouches/overwraps

These comprise paper-based flexible packaging, involving paper with plastics, frequently PE. Where additional barriers are required, aluminium foil or metallised PET is incorporated. This packaging requires a heat sealable layer on the inside of the packaging material. Cold seal coatings on the inside of the packaging material can be used for sealing where the product is heat sensitive.

These types of packaging are usually associated with form, fill seal machinery. Horizontal form/fill/seal machines are of two main types. There are those that form a pouch in a horizontal plane with the product filled vertically. These machines can form a base gusset (Fig. 8.11).

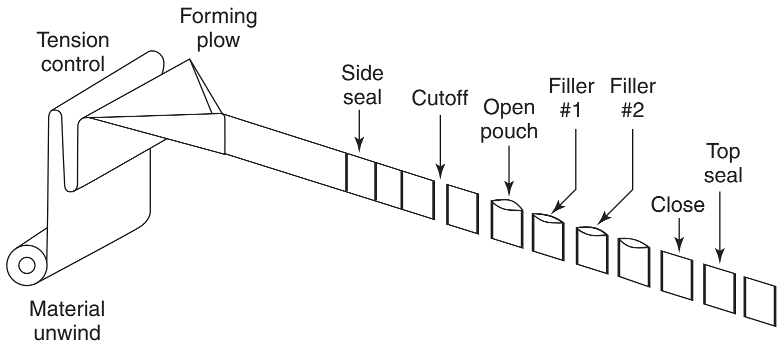

Fig. 8.11 Horizontal pouch/sachet form/fill/seal machine for dry mixes (soups, sauces, etc.). (Courtesy of The Packaging Society.)

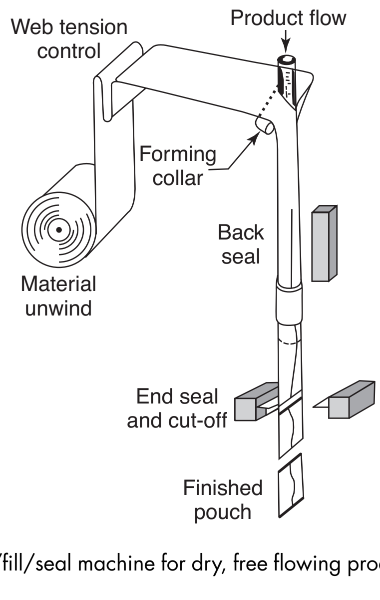

Fig. 8.12 Vertical sachet form/fill/seal machine for dry, free flowing products (snack foods, etc.). (Courtesy of The Packaging Society.)

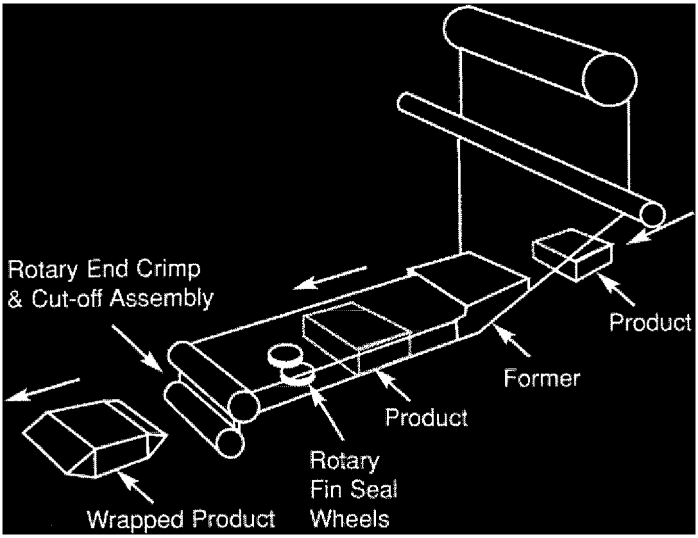

Fig. 8.13 Horizontal, flowrap type, form/fill/seal machine for solid products. (Courtesy of The Packaging Society.)

Vertical form/fill/seal machines are used to pack free-flowing food materials and liquids. Packs made in this way are either flat, or incorporate gussets and block (flat) bottoms (Fig. 8.12).

There is also the flow wrap type that is used to pack single solid items horizontally, such as confectionery bars or multiple products already collated in trays (paperboard) (Fig. 8.13).

There are machines that form bags around mandrels, sealing being made with adhesives, so that they have a rectangular cross section and a block bottom. (This type of machine can also wrap a carton around the paper on the same mandrel to form a lined carton.)

Roll wrap machines pack rows of items, e.g. biscuits and sugar confectionery. Individual confectionery units may be wrapped in waxed paper for moisture protection and to prevent them sticking together.

Overwrapping square or rectangularly shaped cartons, with paper coated with PE or wax with neatly folded heat sealed end flaps is also used, e.g. confectionery.

8.8.4 Multiwall paper sacks

Multiwall paper sacks are made from between two and six plies or layers of paper. The specifications vary according to the needs of the product and the output required. The differences concern the design of opening through which the product is filled, the design of the opposite end, the closure and the style of the sides, which may be a single crease or gussetted for ease of stacking (Fig. 8.14).

The open mouth sack is closed either by sewing through a strip of creped paper folded over the edges of what was the opening, or with a metal tie. The other design of opening is the valve, a small paper tube, inserted in one corner of a pasted end, again there are several basic designs.

The main type of paper used is natural brown kraft paper, which has good strength properties relating to tensile strength,% stretch, tensile energy absorption, burst strength, tear strength and where necessary, wet strength. Air permeability is important for the filling rate of powders in

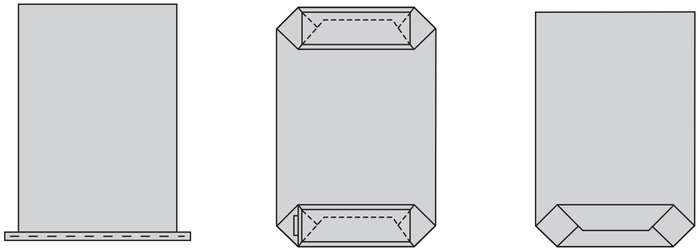

Fig. 8.14 Multiwall sacks.

valved sacks and any sack filling of an aerated product. Water absorption can be important. Surface friction is relevant to pallet stacking and safety.

Where the product requires moisture protection, the moisture vapour transmission rate is important, and there are various ways of achieving a low rate from the use of specially inserted PE bag liners to the use of PE or wax-coated paper, PVdC and aluminium foil laminations.

The use of a bleached kraft outer ply can enhance appearance. Tougher paper in the form of extensible microcreped kraft and creped kraft is also used. Creping gives enhanced stretch properties in the MD of the paper.

Many different food products are packed in multiwall paper sacks. Examples include: sugar, dried milk, whey powder, coffee beans, flour, peanuts, potatoes and other fresh vegetable products. Traditionally, this form of packing was used for the shipment of product in bulk. Smaller multiwall sacks are now used for retail packs. They can incorporate a carrying handle and a window for product visibility, e.g. for potatoes, and also for dry pet food.

8.8.5 Folding cartons

Folding cartons are widely used in the retail packaging of food products. They are paperboard boxes that are supplied to the packaging machine either flat or folded flat. They are used to package a wide range of food products. These range from cereals, frozen and chilled foods, ice cream, chocolate and sugar confectionery, cakes and biscuits, coffee, tea, convenience food mixes (snack soups), dried food products (raisins) and food supplements in the health care market.

Products may be packed in direct contact with the inside of the paperboard, or they may have already been packed in another form of packaging, such as a can, bottle, sachet, bag, collapsible tube, plastic trays or pots.

The choice of paperboard used for folding cartons depends on the needs of the product in packing, distribution, storage and use, and on the surface and structural design. The basic choice is between solid bleached board (SBB), solid unbleached board (SUB), folding box board (FBB) and white lined chip board (WLC).

The protective properties of the paperboard may have been enhanced by the laminations, dispersion coatings, plastic extrusion coatings and other treatments, already discussed, in order to meet specific product needs.

Folding cartons meet many packaging needs and can be made in a wide variety of designs (Fig. 8.15). Most cartons are rectangular or square in cross section. The type of product to be packed, the method of filling and the way the cartons will be distributed, displayed and used will influence the dimensions and design in general. Rectangular shapes are easy to handle

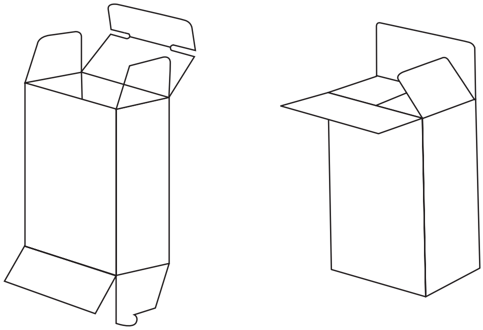

Fig. 8.15 Folding cartons.

mechanically, especially when packed in large volumes at high speeds. The design may be for end loading, e.g. cereals, or top loading, e.g. tea bags.

Paperboard may be formed into trays either by heat sealing, locking tabs and slots or by gluing with hot melt adhesive depending on the application. PET-lined paperboard can be deep drawn to a depth of 25 mm, or 45–50 mm in two stages. This type of tray can be used for a ready meal for frozen or chilled distribution and reheating at up to 200°C in either a microwave or a radiant heat oven. It could have a peelable heat sealable printed paperboard or plastic lid and be packed in a paperboard sleeve or carton (Fig. 8.16).

The early developments in microwave foods provided convenience and rapid heating. It was not suitable for products where browning or a degree of crispness was expected. Developments in microwave food formulations, which improved their performance in the microwave oven, and the use of susceptors in the packs has widened the range of foods suitable for this application. Susceptors absorb microwave energy and heat food rapidly, mainly by contact, and induce crispness and localised browning. Susceptors usually comprise aluminium metallised plastic film, such as PET, laminated to paper or paperboard. Inconel, nickel/chromium, susceptors can be used to induce even higher temperatures. The use of susceptors in this way is an example of *active packaging*.

Cartons may be lined by the carton maker with a flat tube of a flexible barrier material that is inserted during carton manufacture. The flexible material is usually heat sealable – examples include paper/aluminium foil/PE and laminations of plastic films. The lined cartons are supplied folded flat to the packing/filling machine. One end of the liner is heat sealed and after filling, the other end is sealed and the carton flaps closed. This type of carton is used for ground coffee, dry foods and liquids. A lined carton may be fitted with a plastic hinged lid incorporating a tamper evident diaphragm.

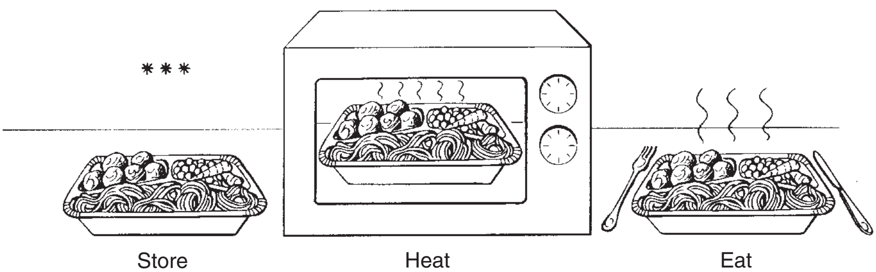

Fig. 8.16 PET lined paperboard trays. (Courtesy of Iggesund Paperboard.)

In another type of lined carton, flat carton blanks and a roll of the material to be used as the liner, frequently bleached kraft paper, are supplied to the packing machine. Firstly, the paper is formed around a solid mandrel. The side seam and base is either heat-sealed or glued with adhesive, depending on the specification. The carton is then wrapped around the liner with the side seam and base sealed with adhesive. The product is filled and both liner and carton sealed/closed. This type of pack is suitable for the vertical filling of powders, granules and products, such as loose filled tea. Folding cartons can have windows or plastic panels for product display, e.g. spirits.

Cartons may have separate lids and bases, flanged or hinged lids. A display outer is a carton that performs two functions. At the packing stage it is used as a transit pack or *outer*. When it arrives at the point of sale the specially designed lid flaps are opened and folded down inside the carton and the transit pack becomes a display pack or *display outer*. This form of pack is frequently used to pack a number of smaller items that are sold separately, e.g. confectionery products also known as *countlines*. On other designs of folding carton, lid panels, or flaps, may close as a tuck-in-flap, flip top, locked, glued or be heat sealed. Closures may be made tamper evident. Lid flaps that are repeatedly opened and closed during the life of the contents require folding endurance strength to withstand repeated opening and reclosure. In addition, cartons can have internal display fitments or platforms, sleeves can be used for trays of chilled ready meals and multipacks for drinks cans, bottles and plastic yoghurt pots. Cartons can incorporate dispensing devices, carrying handles and easy opening tear-strip features for convenience in handling and use. Cartons can be made into non-rectangular, innovative shapes, such as packaging for Easter Eggs.

Cartons can be produced in creatively designed shapes and printed, varnished, laminated or otherwise finished for luxury food products, such as expensive spirits and chocolate confectionery.

Once a specific type of paperboard has been selected, it is necessary to choose a grammage and thickness that will ensure adequate carton strength at each stage of the packing chain from packing through to use by the consumer.

Folding cartons are made as follows: firstly, the surface design is printed on paperboard sheets or reels; secondly, the outline profile of each carton is cut and creased. The flat carton blank that results may be supplied directly to the packer. Alternatively, the flat blank is glued, usually on the side seam and, sometimes, on the base, crashlock style, as well, and folded flat. Both approaches ensure the most efficient use of storage and transit space between the manufacturer and the packer.

There are other processes used in making cartons depending on the surface and structural design. These include varnishing, either in-line with printing or off-line in a separate operation, heat-seal coating for blister packaging, embossing, hot foil stamping, window patching and many more.

8.8.6 Liquid packaging cartons

The concept of a liquid food package based on paperboard became a reality when it became technically possible to combine paperboard with an additional moisture and product resistant heat sealable material. This led to the development of leak-proof liquid tight packaging (Fig. 8.17). The first successful package was the gable-topped Pure-Pak patented in 1915 where wax provided the heatsealable and protective barrier properties.

Several styles of liquid pack were subsequently developed. Most were filled through a full aperture top that was subsequently closed and sealed. The cross sections were square, rectangular

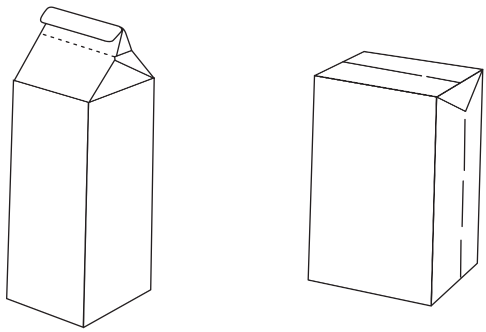

Fig. 8.17 Liquid packaging cartons.

or circular with the sides tapered. They were supplied to the packaging machine either as flat blanks for erection or as nested premade containers ready for filling. PE replaced wax from the 1950s and an additional development led to a reel fed form/fill/seal approach with the tetrahedral-shaped Tetrapak.

A range of shelf life times are possible depending on how the product is processed prior to filling, the filling conditions, and the conditions of distribution. Products could, for example, be pasteurised prior to filling, the product could be filled hot or the product could be UHT sterilised and filled into a sterilised pack, i.e. aseptically packed. An appropriate paperboard laminate would be selected to maintain quality for the period of the required shelf life.

For fresh products, e.g. milk, with a short shelf life in chilled distribution, i.e. 0 to 4°C, a two-side PE coated paperboard is used. For a long shelf life in ambient temperature distribution for hot-filled products and for fresh juices in chilled distribution, the barrier of the laminate is extended by a thin layer of aluminium foil. In this case, the lamination would comprise PE/paperboard/PE/ aluminium foil/PE.

The aseptic packaging process whereby a sterile product is filled into sterile containers and sealed under sterile conditions has been described by the Institute of Food Technologists as 'the most significant food science innovation of the last 50 years'.

This process has been successfully applied to paperboard liquid-packaging to extend shelf life at ambient temperatures. The pack requires the use of the PE/paperboard/PE/aluminium foil/PE laminate. Aluminium foil may be replaced by EVOH, an excellent oxygen barrier, and more easily handled in the domestic waste stream.

The overall result of these packaging, processing and distribution alternatives is that a wide range of liquid-food products are now available in paperboard-based packaging. Examples include milk and milk derived products, juices, soups, non-carbonated water and wine. Liquid products containing particulates are usually filled into open top cartons to eliminate the possibility of product interfering with the sealing of form/fill/seal packs.

A wide range of pack sizes is available from several suppliers. Pack sizes range from the single portion tetrahedral Tetra Classic packs with volumes from 20 to 65 mL, through the popular volume range of packs with square or rectangular cross sections of 0.2, 0.33, 0.5, 1.0, 1.5, and 2.0 L cartons. Several designs of single portion pack are available with straws attached and a 250 mL cylindrical container with an easy-open tab has been introduced by Walki. Even larger 4.0 and 5.0 L cartons are available in the Pure-Pak range.

Whilst pack shapes are dominated by the gable top and brick designs based on square and rectangular cross sections, alternatives are available with shapes based on hexagons, tetrahedrons, wedges, pillow pouch and square cross sections with rounded corners. A major area of design innovation, as a result of consumer demand, in recent years has concerned ease of opening, reclosure and tamper evidence. Many convenience-in-use design features are now available from plastic straws for use with packs having an ease-of-pack-entry feature, plastic screw action closures with a tamper evident feature, peelable foil based tabs and push-fit plastic reclosures, etc.

The production and marketing of liquids in cartons is one of the best examples of the integrated or systems approach to packaging whereby all aspects of the pack, filling and distribution are engineered by the manufacturer of the cartons working closely with the dairy, food processor or in-house own label retail organisation.

The paperboard used in liquid packaging is usually solid bleached, or unbleached board. This is used because it has an efficient performance in printing, cutting, creasing and folding, and particularly, as it is based on pure cellulose fibre, to protect the product from any packaging-related effect on the flavour and taste of the product. Milk and milk derived products, wine and juices are flavour sensitive products requiring careful handling and packaging.

Careful attention is given to printing and extrusion coating and laminating to ensure that the materials and processes used do not have an effect on the flavour of the product. (The large gable-top carton design has also been extended to the packaging of free flowing dry foods, such as rice and freeze dried vegetables for the catering market.)

8.8.7 Rigid cartons or boxes

Rigid cartons, as distinct from folding cartons, are erected before being delivered to the packer. The use of rigid cartons for food packaging is virtually confined to the luxury/gift market, such as for chocolate confectionery, preserves and the more expensive bottled wines and spirits.

Rigid boxes typically comprise a baseboard, the type and thickness of which is chosen to meet the customers needs and which is cut and scored. This is corner stayed, in which gummed paper is fixed around the made up corners of the box providing rigidity. The box is covered with a decorative sheet of paper, or paper, film or aluminium foil based laminate, which is also cut to a precise profile to produce a neat finish. Adhesive secures the lining material, which may be printed, to the board.

A wide range of lining materials can be used to create specific visual effects, such as embossing, hot foil stamping and use of fabric materials. Many features can be incorporated in the design, such as hinges, handles, thumb holes, domes, windows, and plastic and paperboard fitments. Most of the operations are manual or machine assisted, and this together with the wide range of lining materials and design elements makes it possible for a wide range of distinctive box designs to be constructed.

8.8.8 Paper-based tubes, tubs and composite containers

8.8.8.1 *Tubes*

Small diameter paper-based tubes are used for confectionery; they may be designed with paperboard or plastic ends.

8.8.8.2 *Tubs*

Typically, the ice cream tub must be leak-proof, resistant to the product and suitable for low temperature distribution. PE extrusion or wax-coated paperboard meets these needs. Additionally, small tubs are used to pack single portion cream and yoghurt based desserts. Cross sections are circular, elliptical or square with rounded corners. Sides may be straight or tapered.

8.8.8.3 *Composite containers*

These containers are typically of circular cross section though designs with square and rectangular cross sections with rounded corners can also be made (Fig. 8.18). They are used for both dry food products, such as tea, powdered or granular mixes and savoury snack products, and for liquids, e.g. non-carbonated drinks. The container bodies comprise paperboard and paperboard laminates with plastic and seamed-on metal ends with either lever lid, snap-on or seamed ring-pull lids.

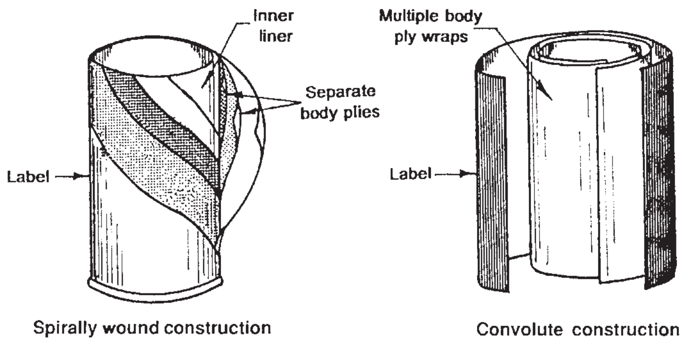

Fig. 8.18 Construction of sidewalls of composite containers. (Courtesy of The Packaging Society.)

8.8.9 Fibre drums

Fibre drums are used to transport food products and ingredients in dry, paste or liquid form. They are usually circular in cross section with parallel-sided walls that are made by winding paper, or thin paperboard, on mandrels. The winding may be either spiral or straight. The paper, or thin paperboard, is usually unbleached kraft (brown) and the layers are adhesive bonded to provide stacking and handling strength.

The drum ends and closures can be based on fibre, metal or plastic depending on the product and distribution needs. The closure method can be by tape, metal lugs or locking metal bands and, depending on the closure, the top rim of the drum may be metal reinforced.

PE inserts or a fully laminated plastic interior with caulked bottom seals may be incorporated. Again, depending on the product, functional barrier materials can be incorporated in the construction as well as special product release coatings.

Drums can be made strong enough to allow four high stacking. They can be made suitable to provide moisture protection in outside storage. Tapered drums and drums with square cross sections incorporating rounded corners can be made. A wide range of drum capacities are available, depending on the product and the method of distribution from small drums up to as high a capacity as 280 L (75 US gal or 62 Imperial gals). Drums can be printed by silk screen, labelled or ink jet printed.

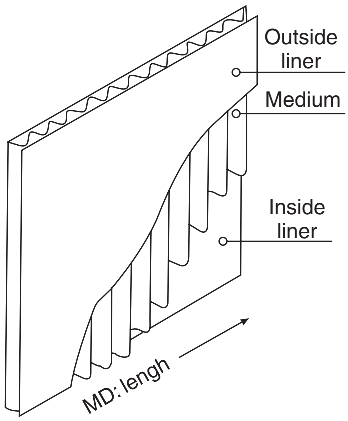

Fig. 8.19 Components of single wall corrugated fibreboard. (Courtesy of The Packaging Society.)

8.8.10 Corrugated fibreboard packaging

This is by far the largest paper and paperboard based sector in terms of the tonnage used. This type of packaging is synonymous with packaging for transportation and storage.

In the retail sector, boxes and trays made from corrugated fibreboard are used as secondary packaging. In the food industry, they are used to pack multiple numbers, e.g. 6, 12, etc., of primary containers for storage and distribution. Corrugated fibreboard typically comprises three layers of paper-based material and this is known as single wall material (Fig. 8.19). There are two outer layers or liners separated by a corrugated inner ply known as fluting. The liner plies are glued to the tips of the fluting. The resulting material has high bending stiffness in relation to the weight, and high compression strength when made up in the shape of a box with glued or taped side seams and end panels. (Side seams and closures using metal staples are not normally permitted for food packaging applications.)

Double wall corrugated fibreboard comprising three liner and two fluting plies is produced but this degree of strength is not normally necessary for multiples of primary food packs.

Triple wall corrugated fibreboard is a thicker and, therefore, stronger material, and this is used with protective inner lining bags, usually made from PE film, for the bulk packaging of free flowing food products and ingredients.

The most common lining ply material is brown kraft liner. This may be unbleached virgin kraft liner, 100% recycled fibre, also known as test liner, or mixtures of both types of fibre, the colour is brown. Bleached, white, liner plies are possible with the use of bleached kraft, and mottled white/brown liners are based on mixtures of bleached and unbleached fibres. The weights range from 115 to 400 g/m^2, though the typical values for food packaging are 125, 150, and 175 g/m^2.

The fluting medium, also known as corrugating medium, may use any of several types of fibre, such as mechanical, chemical or recovered recycled fibre. Several grammages are available in the range (approximately) 90–220 g/m^2. If mechanical fibre is used, it is usually of the semi-chemical type, i.e. mechanical pulp subjected to partial chemical treatment that increases the yield compared with chemical pulp but with strength characteristics that are higher than that of mechanical or recycled pulp of the same weight (grammage). The paper is conditioned with heat and steam, and pressed between large rolls, with a gear wheel-shaped surface, to produce the corrugation (Fig. 8.20).

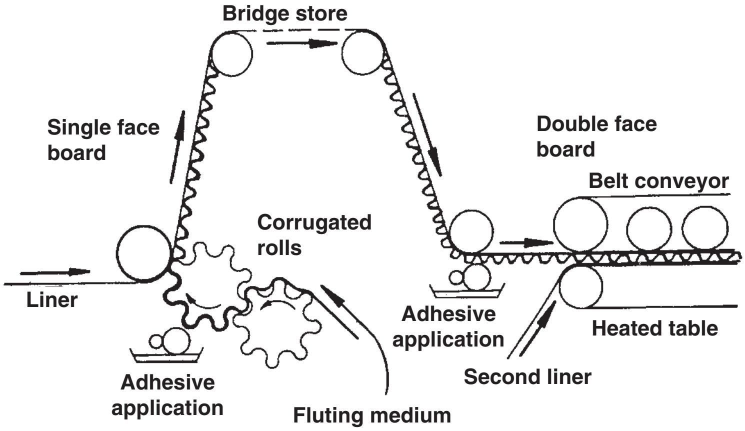

Fig. 8.20 Production of corrugated fibreboard. (Courtesy of The Packaging Society.)

Several standard flute configurations are available varying in the pitch height and number of corrugations per unit length, characterised by letters A (coarse), B (fine), C (medium) and E (finer than B). B-flute has a high flat crush resistance and is used for packing cans and bottles where the contents themselves contribute to the stacking strength. C-flute is used where the contents do not support the case because C-flute has a higher compression strength at the same board weight. It is also used for glass bottles where its higher flute height may provide more cushioning and higher puncture resistance. In addition to box compression, cushioning, flat crush resistance and puncture resistance, other performance features that have to be taken into consideration are print quality, efficiency of cutting and the scoring and bending characteristics. Printing is carried out either after corrugating or, where higher print quality is required, before corrugating. The latter is referred to as *pre-print*.

It is sometimes more appropriate for the packer to purchase an unprinted standard-sized case and print, or label, on demand. This approach may be applied where seasonally cropped fresh fruit and vegetables are being canned, and it is difficult to estimate the eventual size of the crop and, therefore, the number of printed cases required. If the estimate is above the eventual requirement, printed cases are left in stock until the next packing season occurs, and if underestimated there is a need for urgent deliveries of additional printed cases.

Box compression strength can be calculated from the weight of contents, stacking geometry, and atmospheric conditions of storage. The manufacturers of corrugated packaging have mathematical models based on their standard materials, type of fluting, dimensions and weight of contents that can predict the compression strength of cases. Hence, it is possible to estimate the weight of material and type of fluting that should provide adequate compression strength after an appropriate safety factor has been taken into consideration.

The most common design of case used in the food industry is the RSC, regular slotted container. In this design, all the perimeter cutting, cutting of slots, which enable the flaps to fold neatly despite the thickness of the material, and the scoring or indenting to provide creasing and folding are carried out in straight lines in both MD and CD. Diecutting is necessary for special designs incorporating cutouts, curves and angles. Designs with these features are sometimes used in the food industry in conjunction with stretch or shrink wrapping to create more visual impact in cash-and-carry sales outlets.

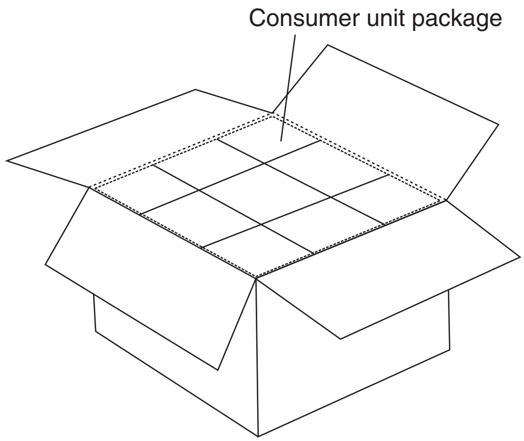

Fig. 8.21 Transit package can be a corrugated fibreboard case containing a fixed number of unit packages. (Courtesy of Iggesund Paperboard.)

Retail-ready secondary packs are now designed to suit their use in distribution and which are still easily and efficiently converted to a supermarket shelf display unit, which makes the product easily visible and accessible to the customer whilst also being easily disposable.

Other designs of transit pack using corrugated fibreboard are typically the wrap around case erected on the packing line and the tray type packs of which there are many versions (Fig. 8.21). Some are, subsequently, stretch or shrink wrapped and some are erected around the primary packs to provide stacking strength and partial visability of the primary packs without any overwrapping plastic film.

Retail Ready Packaging is a term that describes secondary packaging that is designed to incorporate features that assist handling in distribution, efficient merchandising on self-service shelves in supermarket, help customers to see and access the products on the shelves as well as being easily disposable.

8.8.11 Moulded pulp containers

The most common food packaging applications for moulded-pulp containers are the egg packs and the trays used for apples and other fresh produce.

Moulded pulp containers are made directly from a suspension of fibre in water, using a mould in the form of a screen through which water is removed.

Usually recovered mixed fibres are grey in colour. If a lighter colour is required, bleached pulp, which can also be recovered fibre, of an appropriate grade is used. If other colours are required the pulp can be dyed.

There are two main processes of manufacture. The pressure injection process uses hot air under pressure to form the container that is further heated to remove excess moisture and sterilise the pack. In the other process, vacuum is applied to remove water from the mould. This process has a higher residual moisture content that has to be reduced by drying but the surface is smoother making for an improved printing result, where the packs are printed. Labelling is an alternative to printing.

8.8.12 Labels

Labels in the context of food packaging comprise the labels that are applied to:

- primary packaging in the form of cans, bottles, jars, pots, tubs, cartons, corrugated fibreboard cases, fibre drums and moulded pulp containers
- transit packs (secondary packaging), such as cases and stretch/shrink wrapped packs
- palletised loads (tertiary packaging)
- the food product directly (promotional labels), e.g. fruit

Labels for food packaging identify, promote, inform, offer advice on the use of the products concerned and, where, for instance, a label is applied over a closure, provide security as a tamper evident feature.

Labels are characterised by their substrate, adhesion and method of application. The substrate may be paper, paperboard and laminates thereof to aluminium foil and plastic films. There is a wide choice of paper-based substrate depending on the appearance and finish required. The paper may be uncoated, on-machine white mineral pigment coated in matte, satin or gloss finishes, or cast-coated off-machine with white or coloured mineral pigment coatings. Where laminates to aluminium foil are used they are often embossed.

Labels may use any of the conventional print processes, the choice being influenced by the order quantity and finished appearance required. Digital printing is also used, as is ink jet printing, on the packing line. Varnishing is applied to provide protection, e.g. wet rub resistance, and gloss. Hot foil stamping is used to enhance appearance.

Dextrine adhesives are used with ungummed labels for the high-speed labelling of metal and glass containers. Processed food cans and beer in glass bottles may be labelled at speeds up to 80 000 per hour. This process is known as *wet labelling*. Hot melts are used with ungummed labels on plastic containers.

Ungummed labels are usually supplied stacked in small bundles already cut to the required dimensions and shape. Where labels are picked up, held or transferred by vacuum, it is essential that the substrate is not too porous to air.

Where the substrate is wetted as with dextrine adhesives, care in the choice of paper is necessary to ensure that an excessive amount of curl does not develop. When moisture is applied to paper it causes the fibres to swell more significantly in the CD and as more fibres tend to be oriented in the MD, the paper would tend to form a cylinder with its axis parallel to the MD – this type of curl is known as CD curl. It is necessary to use paper with a low MD/CD ratio, i.e. less MD orientation bias. As with all paper and board based packaging products, it is also important to ensure that flatness is maintained in printing, storage and end use at the packaging stage.

Some ungummed labels are applied to packaging without the use of adhesives, such as those tied on tags, and labels slipped on to the necks of bottles or otherwise clipped in place. These labels are often used with luxury food products, confectionery and drinks.

Labels supplied on reels with the adhesive already in place are referred to as being self-adhesive or pressure sensitive. As the adhesive is tacky, the label stock is combined with a backing or carrier web during manufacture. The backing web comprises either glassine or bleached kraft with a siliconised surface in contact with the adhesive. The label profile is cut on the backing web; this requires a very precise control of the cutting process, since whilst the label perimeter must be cleanly cut the backing web must remain undamaged. At the point of application the label leaves the backing web, and the skeletal waste label stock and the carrier web are reeled up.

In terms of packing line speeds, self adhesive labels can be used over a very wide range from semi-automatic manually assisted lines running up to 30 units per minute to automatic lines that can be designed to run at speeds from 60 to 600 per minute. Another advantage of these labels is that changing over from one label to another on the packing line is easy.

The adhesive coating on self adhesive labels must be chosen to meet functional needs, such as whether the label is to be permanent or removable, and whether there are extremes of temperature involved, e.g. frozen food storage.

Paper or paperboard in-mould labels are associated with plastic packs where the label is inserted into the tooling of an injection moulding, blow moulding or thermoforming. In-mould labels require a heat sealable coating on the reverse side, which is compatible with the plastic being used for the container so that the label fuses with the container during the forming process.

There are several advantages possible with in-mould labelling. Firstly, a high quality printed image can be achieved more cost effectively than can be achieved by direct printing on round straight sided, tapered or otherwise-shaped containers. Secondly, where the product requires high barrier properties, labels based on laminates of paper or paperboard to aluminium foil can give the required protection. Thirdly, with some designs of in-mould labelled container the weight of plastic used can be reduced whilst maintaining product protection and container compression strength.

A printed thin paperboard label may be side seam glued so that it is tightly applied to a tapered plastic pot in such a way that after use the label and plastic components can be easily segregated for recycling (Sandherr K3 tub from Greiner Packaging).

Heat transfer labelling, e.g. by the Dennison Therimage process, is based on a paper carrier web with a wax coating on one side. The image is reverse printed on the wax coating, which is then coated with a heat sensitive adhesive. At the point of application to a plastic container the image is transferred from the paper carrier web by heat and pressure.

In recent years, there have been significant developments in smart, intelligent or chip-based labels that are being used for identification, traceability, track and trace and smart logistics applications. Many of these applications use RFID (radio frequency identification) technology.

Data is stored on an RFID tag that carries data programmed into a small computer chip that operates at a wide range of frequencies activated from an RFID reader. The tag using a label can be applied to pallets, cases of unit packs and unit packs themselves. It is not always necessary to use a label. Pills have had an RFID edible tag applied. The data most frequently stored concerns supply chain information and control but it can also involve other smart uses, such as data concerning the use of a pharmaceutical product.

8.8.13 Sealing tapes

Sealing tapes are narrow width reels comprising a substrate and a sealing medium that can be dispensed and used to close and seal corrugated fibreboard cases, fibre drums, rigid boxes and folding cartons. Sealing tapes are also used to make the side seam manufacturers join on corrugated fibreboard cases and tape the corners of rigid boxes, thereby erecting or making-up corner stayed boxes.

A traditional and commonly used substrate is hard-sized kraft paper, both unbleached (brown) and bleached (white). Where higher strength is required the kraft is reinforced with glass fibre, and up to four progressively stronger specifications are typically available from some suppliers.

Reel widths start at 24 mm, though 50 mm width tape would be a typical width to seal the flaps of an average sized corrugated fibreboard case.

In the case of gummed tape, adhesion is achieved by coating the kraft paper with a modified starch adhesive; animal glue has largely been superseded. The adhesive is then dried and the reels are slit to size. In subsequent use, the adhesive is automatically, and evenly, reactivated by water in a tape dispenser. Tape dispensers that can cut pre-set lengths for specific taping specifications are available.

The advantage of gummed paper tape is that it is permanent and provides evidence of tampering, it can be applied to a dusty pack surface without loss of adhesion, is not affected by extremes of heat and cold and does not deteriorate with time. Pressure sensitive tapes, on the other hand, are used on all types of packaging from paper and paperboard to metal, glass and plastic containers. Pressure sensitive adhesive can be applied to several types of substrate, including moisture resistant kraft paper that is coated on the other side with silicone to facilitate dispensing from the reel.

Heat fix tapes are based on kraft paper where the adhesive is applied as a thermoplastic emulsion that is subsequently reactivated by heat and applied to the sealing surface by pressure. Sealing tapes are used plain, preprinted or printed at the point of application.

8.8.14 Cushioning materials

Paper-based cushioning comprises:

- shredded paper used as a loose fill packing – this is a good use for clean recovered paper – not widely used in food packaging
- interlocking dividers used to separate, for example, bottles in a case
- corrugated fitments made up of one or several layers of corrugated fibreboard cut to special profiles to support, locate and protect vulnerable profiles of items. Not specifically used in food packaging but widely used in products associated with the cooking and storage of food
- moulded pulp applications (already mentioned under Section 8.8.11 above for eggs and apples)

8.8.15 Cap liners (wads) and diaphragms

There are a number of ways of ensuring a good seal when a lid is applied to a jar, bottle or similar rigid container:

- *pulpboard disk*: The simplest type of cap liner is a pulpboard disk made from mechanical pulp fitted inside a plastic cap. This cap liner or wad has to be compressible and inert with respect to the contents of the container. This liner could be faced with aluminium foil or PE where the nature of the contents require separation from direct contact with the pulpboard
- *induction sealed disk*: The disk comprises pulpboard/wax/alumium foil/heat seal coating or lacquer. The cap with the disk in place is applied to the container and secured. It then passes under an induction heating coil. This heats the aluminium foil, which causes the wax to melt and become absorbed in the pulpboard. It also activates the heat seal coating and seals the aluminium foil to the perimeter of the container. When the consumer removes the cap the adhesion between the pulpboard and the aluminium foil breaks leaving the foil attached to

the container. This seal therefore provides product protection and tamper evidence. Where subsequent contact between the contents and the pulpboard is undesirable, the pulpboard is permanently bonded to the aluminium foil. (A simpler version dispenses with the wax and replaces the pulpboard with paper.)

8.9 SYSTEMS

There are many examples today of a total systems concept involving one packaging company acting in partnership with the food manufacturer in an integrated system from the point of packing and processing to the point of sale.

Paper and paperboard based packaging systems for food products implies consideration of:

- the functional needs of packaged preserved foods
- how these needs are met by paper- and paperboard-based materials and the packaging made from such materials
- packaging machinery
- integration of food processing with packaging, storage and distribution

One of the best examples of this type of packaging system is the aseptic packaging of milk and juice products in paperboard-based liquid packaging.

The term *packaging system* may also be used in a more limited way where a packaging material supplier, working in partnership with a product manufacturer, supplies packaging material, leases the packaging machinery and takes responsibility for technical support and maintenance of the machinery.

8.10 ENVIRONMENTAL PROFILE

Paperboard has a low environmental impact in that the main raw material, wood, is naturally sustainable (Fig. 8.22). Wood is derived from trees, and in order to grow naturally trees need:

- sun (energy)
- soil
- water
- air (carbon dioxide)

Wood is derived from forests. Forests are essential for the well-being of the world environment by:

- reversing the greenhouse effect (by absorbing carbon dioxide)
- stabilising climate and water levels
- preventing soil erosion
- storing solar energy

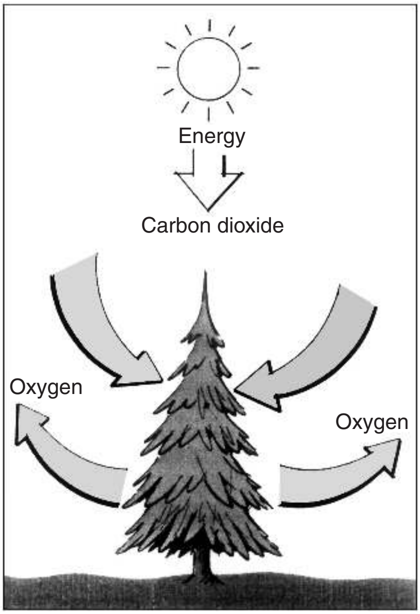

Fig. 8.22 Trees grow by the combination of carbon dioxide and water, using energy from the sun. This process, which emits oxygen, is known as photosynthesis. (Courtesy of Iggesund Paperboard.)

The commercial use of wood for paper and board needs is met by sustainable forest management, which:

- ensures replenishment of trees
- provides habitats for animals, plants and insects
- promotes biodiversity
- protects watercourses
- preserves landscape
- maintains rural employment
- creates recreation facilities

Forest management today meets commercial, social and environmental needs, and forests can be independently audited and certificated for environmental performance. Certification was introduced by the Forest Stewardship Council (FSC), and other schemes were subsequently set up, such as the Program for the Endorsement of Forest Certification (PEFC), to meet specific regional forest needs (Cepi, 2008a).

There is understandable public concern at the loss of forests worldwide. It is however important to differentiate between sustainable commercial forestry undertaken by the paper industry and the clearing of forests in the less well developed parts of the world, mainly in the southern hemisphere, where this is done to meet the needs of land hunger and where wood is the only source of fuel. The forest area in the northern hemisphere is increasing annually and the amount of wood cut is exceeded by the amount of new growth in existing trees. In the southern hemisphere there is an increase in the new plantation forest areas. Over 50% of wood cut annually worldwide is used for fuel and a large amount is used for construction.

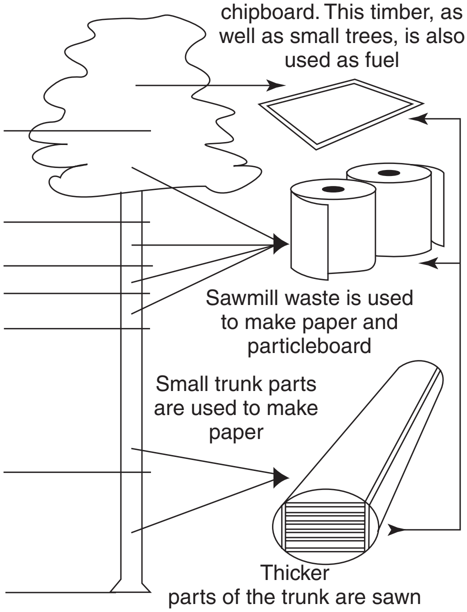

Fig. 8.23 How the tree is used. (Courtesy of Iggesund Paperboard.)

The paper and board industry uses 10% of the wood harvested annually. It uses thinnings, the tops of large trees and saw mill waste, i.e. materials that otherwise would become waste (Fig. 8.23). Commercial forestry for the paper industry is leading to an increase in both the land area devoted to forestry and the volume of wood growing in those forests.

A major advantage of paper and paperboard is that it can be recycled as fibre and used to make new paper and paperboard materials (Fig. 8.24). As a result, 50% of the world's fibres for paper making are provided by recovered paper and paperboard products. Pulp recovery from waste paper and board is an example of material recycling and between 40 and 60% of paper and board is recovered in Europe and North America. Commercial and industrial waste paper is relatively easy to collect and systems have been in place for 100 years or so where the driving force was based on commercial viability. In recent times, attention has been focussed on domestic or post-consumer waste. Systems are being developed to segregate and recover more paper and board from this source.

Packaging accounted for 41% of all paper and board consumption in Europe in 2008 (CEPI, 2008b). Many paper and paperboard packaging products are based on recovered paper and board. The infrastructure for recovery is based on merchants and a categorisation of the various types of waste paper and board. Prices of the various grades depend on the fibre quality and the market forces of supply and demand. A quality described as 'clean white shavings arising from mills or printers trimmings' is in quality terms almost as good as virgin pulp and is high priced. Mixed unsorted waste has the lowest price.

Pulp is a worldwide commodity and a mix of recycled and virgin pulp is necessary to meet the overall needs of the market in terms of quality and quantity. Paper consumption is rising in the Far East, especially in China, and much of this demand is being met with recovered fibre. However, 100% recovery and reuse is impossible. This is because some grades by nature of their

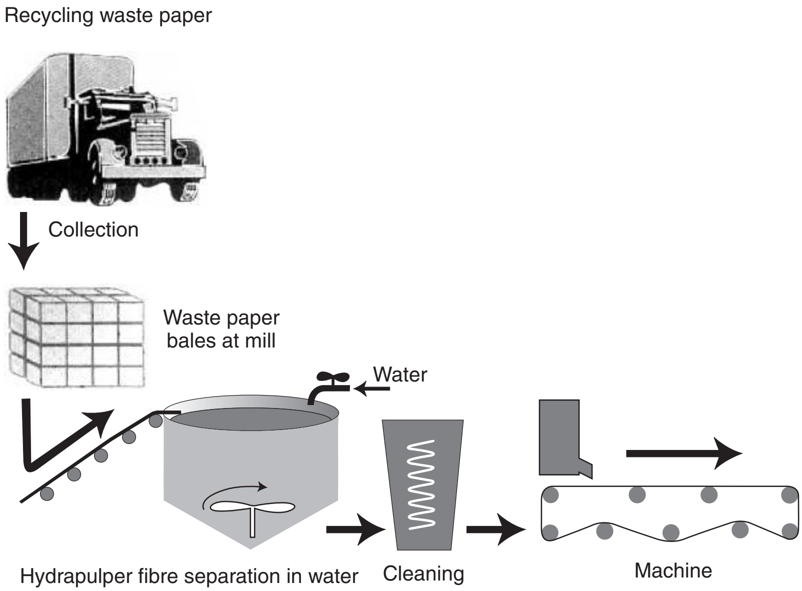

Fig. 8.24 Recovery and recycling of waste paper and paperboard. (Courtesy of Pro Carton.)

use cannot be recovered and the fact that multiple recycling causes fibre quality and quantity to deteriorate. Hence, there is an ongoing need to provide new virgin fibre.

Energy is another major resource. Pulp made by the chemical separation of fibres, and paper and paperboard mills integrated with such pulping use biomass energy, i.e. the non-cellulose components of wood are used as fuel.

Pulp derived from wood by mechanical means and from recovered waste paper and paperboard does use fossil fuel but in the past 10 years significant increases in efficiency have been achieved by the use of combined heat and power plants. A number of mills with access to biofuels, such as wastes from forestry, have switched from the use of fossil fuels to biofuels thereby emphasising the sustainable nature of their energy use.

Other environmental aspects are:

- *bleaching (pulp mill effluents were considered harmful)*: The problem was due to the use of chlorine gas (elemental chlorine). This process has been replaced and today the by-products are harmless
- *use of water and subsequent contamination of water courses by paper and board mill effluent*: Such effluent was a cause of concern in the past because it reduced biological oxygen and hence affected marine life. This has been tackled by effluent treatment within mills so that water emissions are not harmful in this way
- *overall water consumption*: More water is now recycled within the mill. Some pulp mills today have no water emissions
- *paper-based packaging is said to be a waste of resources*: It is necessary today to be able to demonstrate that the amount of packaging used is not excessive and that it is commensurate with the protection needs of the product thereby preventing product wastage
- where paper and paperboard materials are not suitable for material recycling they can still be useful as a source of energy, i.e. incineration with energy recovery, or compost

Overall paper and board is a naturally renewable (sustainable) product that does not pollute the environment in the course of manufacture and use. It is recyclable as material, energy or compost and, if none of these processes is practical, it is biodegradable.

The EU has funded a research project (SustainPack) concerning fibre-based sustainable packaging involving 35 partners from packaging research associations, universities and industry. This work examined many aspects of fibre-based packaging linked with other technologies, such as nanotechnology and the incorporation of tagging, such as that using chip-based radio frequency identification (RFID). The work examined packaging users needs for freshness indication, article surveillance, printed electronics and many other features (SustainPack, 2008).

8.11 CARBON FOOTPRINT

The paper and paperboard industry is well placed to help in combating climate change resulting from an increase in greenhouse gases in the atmosphere. The total carbon dioxide emission, together with the carbon dioxide equivalents of other greenhouse gases associated with a product, process or service is known as its carbon footprint. This is calculated by studying the emissions at each stage in the life cycle of the product, process or service.

There are Life Cycle ISO Standards for Life Cycle studies. However, the setting of the boundaries for the life cycle studies is discretionary. Whilst a particular process may be examined to investigate possible improvements in emissions reduction, there is also a current trend for the carbon footprints of different products to be compared, and this requires conformity of approach for comparisons of the data to be meaningful.

In Europe CEPI (Confederation of the European Paper Industry) has developed a common framework that enables its members to calculate carbon footprints. The framework defines the various sources of carbon dioxide and carbon dioxide equivalents to be investigated, and they should be calculated. Companies and industry sectors are able to include other elements that address their needs whilst ensuring that the information is transparent and well presented to paper and paperboard users (CEPI, 2007).

The ten considerations, referred to as the 'toes' of the carbon footprint discussed in the CEPI Report are discussed below.

8.11.1 Carbon sequestration in forests

As we have seen trees grow by removing carbon dioxide from the atmosphere. Trees grow in forests and fulfil a number of commercial, environmental and community needs.

The demand for wood in Europe has ensured that forest area is high and is increasing. The volume of new wood grown per year has exceeded the volume harvested by 27% in the period 1990–2004. The industry therefore stimulates carbon dioxide retention in the forests.

The biomass carbon in the wood harvested for paper and paperboard can be calculated. A lot of this energy is, depending on the pulping process, used during manufacture and the carbon returned to the atmosphere. The rest is bound in the product but ultimately at the end of life in either landfill or energy-from-waste it is also returned to atmosphere.

Quantitatively, therefore, bioenergy carbon has a low or even zero emissions effect for some products in the footprint calculation. It is, however, of considerable importance qualitatively for the stimulus it provides for environmentally sound forest management, for sustainability in wood availability, societal support for forest communities and to encourage the use of wood in other areas where otherwise products of a higher carbon footprint, such as fossil fuels, alternative building materials and alternative packaging materials would have to be used.

8.11.2 Carbon stored in forest products

The extent of time during which carbon storage in paper and paperboard is retained is dependant on the product. Forest product wood used in buildings last for a very long time – also products used in legal documents, libraries, galleries and museums.

With packaging the lifespan is much less. Some 40% of paper and paperboard produced is used in packaging. In the main and, particularly with food and beverage packaging, the pack is disposed of after use when it is either recovered for recycling or disposed of in landfill or in an energy-from-waste facility. When recycled the bioenergy in the fibre is retained, when used to produce energy it replaces the use of energy from another source, which may well be fossil-based. In landfill, the bioenergy emissions of methane occur, though there are installations that collect and use landfill methane for energy.

8.11.3 Greenhouse gas emissions from forest product manufacturing facilities

Manufacturing occurs in pulp mills, paper and paperboard mills and the facilities used to print and convert these products into packaging. The greenhouse gas emissions we are concerned with are those arising from the use of *fossil* fuels and not those from *biofuel* or as it is also called, *biomass*. Pulp mills and pulp mills operating alongside paper and paperboard mills where the cellulose fibres are separated chemically use little or no fossil fuel as most of the energy required is bioenergy derived from the non-cellulose components of the wood. Mills separating fibres by mechanical means use electricity though this may be made using biomass energy.

8.11.4 Greenhouse gas emissions associated with producing fibre

These emissions include those from harvesting wood and forest management and those from the collection, sorting and processing of recovered waste paper and paperboard.

8.11.5 Greenhouse gas emissions associated with producing other raw materials/fuels

These emissions are those concerned with the manufacture of chemicals and other additives in paper, paperboard and packaging manufacture and in the manufacture of the fuel that is used. They also include emissions involved with the electricity purchased for the manufacture of the chemicals and additives.

8.11.6 Greenhouse gas emissions associated with purchased electricity, steam and heat, and hot and cold water

These emissions are from purchased electricity, steam and heat used to manufacture paper, paperboard and packaging.

8.11.7 Transport-related greenhouse gas emissions

These emissions are from all the forms of transport used from taking wood to the pulp mill or chipping plant to the transport of waste at the end-of-life.

8.11.8 Emissions associated with product use

These are usually zero for forest products.

8.11.9 Emissions associated with product end-of-life

These are mainly those from anaerobic decomposition of forest products in landfill. They do not include biogenic energy emission released in an energy-from-waste plant.

8.11.10 Avoided emissions and offsets

This category is optional and its use in emission balance sheets is controversial since it involves the calculation of emissions that are avoided by the use of forest products. An example is when a mill exports electricity from biomass where if this did not occur the electricity would have had to be made by using fossil fuel. Another would be to calculate the emission avoided if mill bark waste is used on farmland where if it were not used a chemical fertilizer based on fossil fuel would have had to be used. It is, therefore, important that the assumptions and methods used to calculate avoided emissions are transparent and explainable to those interested.

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