# PAPER AND PAPERBOARD PACKAGING TECHNOLOGY

Edited by

MARK J. KIRWAN
Consultant in Packaging Technology
London, UK

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# Paper and Paperboard Packaging Technology

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# Preface

This book discusses all the main types of packaging based on paper and paperboard. It considers the raw materials and manufacture of paper and paperboard, and the basic properties and features on which packaging made from these materials depends for its appearance and performance. The manufacture of twelve types of paper- and paperboard-based packaging is described, together with their end-use applications and the packaging machinery involved. The importance of pack design is stressed, including how these materials offer packaging designers opportunities for imaginative and innovative design solutions.

Authors have been drawn from major manufacturers of paper- and paperboard-based packaging in the UK, France and the USA. The editor has spent his career in technical roles in the manufacture, printing, conversion and use of packaging.

Packaging represents the largest usage of paper and paperboard and therefore both influences and is influenced by the worldwide paper industry. Paper is based mainly on cellulose fibres derived from wood, which in turn is obtained from forestry. The paper industry is a major user of energy, and is therefore in the forefront of current environmental debates. This book discusses these issues and indicates how the industry stands in relation to the current requirement to be environmentally sound and the need to be sustainable in the long term. Other issues discussed are packaging reduction and the options for waste management.

The book is directed at those joining companies which manufacture packaging grades of paper and paperboard, companies involved in the design, printing and production of packaging, and companies which manufacture inks, coatings, adhesives and packaging machinery. It will be essential reading for students of packaging technology.

The 'packaging chain' comprises:

- Those responsible for sourcing and manufacturing packaging raw materials.
- Printers and manufacturers of packaging, including manufacturers of inks, adhesives, coatings of all kinds and the equipment required for printing and conversion.
- Packers of goods, for example within the food industry, including manufacturers of packaging machinery and those involved in distribution.
- The retail sector, supermarkets, high street shops, etc., together with the service sector, hospitals, catering, education, etc.

The packaging chain creates a large number of supplier/customer interfaces, both between and within companies, which require knowledge and understanding. The papermaker needs to understand the needs of printing, conversion and use. Equally, those involved in printing conversion and use need to understand the

technology and logistics of papermaking. Whatever your position within the packaging chain, it is important to be knowledgeable about the technologies both upstream and downstream from your position.

Packaging technologists play a pivotal role in defining packaging needs and cooperating with other specialists to meet those needs in a cost-effective and environmentally sound way. They work with suppliers to keep abreast of innovations in the manufacture of materials and innovations in printing, conversion and use. They are aware of trends in distribution, retailing, point-of-sale/dispensing, consumer use, disposal options and all the societal and environmental issues relevant to packaging in general.

# Acknowledgements

My thanks go to the contributing authors and their companies. It is not easy these days to find time for such additional work, and their contributions are much appreciated.

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In particular, I would like to acknowledge the help that I have received from the following:

Iggesund Paperboard, The Institute of Packaging, the Confederation of European Paper Industries (CEPI), Pira International, Pro Carton, British Carton Association, Swedish Forest Industries Federation, PITA, Paper Federation of Great Britain, INCPEN, M-real, Stora Enso, Bobst SA, AMCOR (flexibles for food and healthcare packaging), Billerud Beetham (manufacturer of medical packaging paper, formerly Henry Cooke), Bill Inman (former Technical Manager at Henry Cooke), Alexir Packaging (folding cartons), Papermarc Merton Packaging, Kappa Packaging, Kappa Lokfast, Tetra Pak, Elopak, SIG Combibloc, Rose Forgrove, Marden Edwards, Robert Bosch Packaging Machinery, Rovema Packaging Machines, IMA (tea packaging machinery), Dieinfo, Bernal, Atlas, Michael Pfaff (re. rotary cutting and creasing), Diana Twede (School of Packaging, Michigan State University), Neil Robson (re. packaging issues in relation to the Developing World), National Starch and Chemical (adhesives), Sun Chemical (inks), Paramelt (coating and laminating waxes), Smith Anderson (recycling and packaging products), Interflex Group (wax/paper flexible packaging), John Wiley & Sons (publishers).

This book would not have been attempted without the experience gained in my packaging career, for which I thank former colleagues, especially those with whom I have been in contact recently: Reed Medway Sacks, Bowater Packaging (carton, paper bag and flexible packaging manufacture), Cadbury Schweppes (foods packaging), Glaxo (ethical and proprietary pharmaceuticals packaging), Thames Group (paperboard manufacture) and, in particular, Iggesund Paperboard, who encouraged me to become involved in technical writing.

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I am indebted to Professor Frank Paine, whom I first met as a colleague in Bowater in the 1960s, for his cheerful support and encouragement during the writing, and for reading and commenting constructively on the drafts of the manuscript. He has nearly 60 years of international experience in packaging technology and a substantial involvement in authorship and editing. His practical advice and patience has been much appreciated.

*Mark J. Kirwan*

# 1 Paper and paperboard – raw materials, processing and properties

Mark J. Kirwan

## 1.1 Introduction – quantities, pack types and uses

Paper and paperboard are manufactured worldwide. The world output for the years quoted is shown in Table 1.1. The trend has been upward for many years.

Paper and paperboard are produced in all regions of the world. The proportions produced per region in 2003 are shown in Table 1.2.

Paper and paperboard have many applications. These include newsprint, books, tissues, stationery, photography, money, stamps, general printing, etc. The remainder comprises packaging and many industrial applications, such as plasterboard base and printed impregnated papers for furniture. In 2000, paper and paperboard produced for packaging applications accounted for 47% of total paper and paperboard production (PPI, 2002).

**Table 1.1** World production of paper and paperboard

| Year | Total tonnage (million tonnes) |
|---|---|
| 1980 | 171 |
| 1985 | 193 |
| 1990 | 238 |
| 1995 | 276 |
| 1998 | 300 |
| 1999 | 315 |
| 2000 | 324 |
| 2001 | 318 |
| 2002 | 339 |

*Source*: PPI, 2002.

**Table 1.2** World production % of paper and paperboard by region for 2003

| Region | % Production |
|---|---|
| Europe | 30.7 |
| Latin America | 4.8 |
| North America | 29.6 |
| Africa | 1.1 |
| Asia | 32.7 |
| Australasia | 1.1 |

*Source*: PPI, 2002.

As a result of the widespread uses of paper and paperboard, the apparent consumption of paper and paperboard per capita can be used as an economic barometer, i.e. indication, of the standard of economic life. The apparent consumption per capita in the various regions of the world in 2000 is shown in Table 1.3.

**Table 1.3** Apparent per capita consumption of all types of paper and paperboard in 2000

| Location | Apparent consumption (kg) |
|---|---|
| North America | 303.3 |
| European Union | 201.0 |
| Australasia | 147.6 |
| Latin America | 34.8 |
| Eastern Europe | 31.4 |
| Asia | 28.2 |
| Africa | 6.1 |

*Source*: PPI, 2002.

The per capita usage figures provide an interesting contrast between different regions, with 31% of consumption occurring in North America, 27% in Europe and 30% in Asia.

The manufacture of paper and paperboard is therefore of worldwide significance and that significance is increasing. A large proportion of paper and paperboard is used for packaging purposes.

About 28% of the total output is used for corrugated and solid fibreboard and the overall packaging usage is significant. Amongst the membership of CEPI (Confederation of European Paper Industries), 40% of all paper and paperboard output is used in packaging.

Not only is paper and paperboard packaging a significant part of the total paper and paperboard market, it also provides a significant proportion of world packaging consumption. Up to 40% of all *packaging* is based on paper and paperboard, making it the largest packaging material used, by weight. Paper and paperboard packaging is found wherever goods are produced, distributed, marketed and used.

Many of the features of paper and paperboard used for packaging, such as raw material sourcing, principles of manufacture, environmental and waste management issues, are identical to those applying to all the main types of paper and paperboard. It is therefore important to view the packaging applications of paper and paperboard within the context of the worldwide paper and paperboard industry.

According to Robert Opie (2002), paper was used for wrapping reams of printing paper by a papermaker around 1550, the earliest printed paper labels were used to identify bales of cloth in the sixteenth century, printed paper labels for medicines were in use by 1700 and paper labels for bottles of wine exist from the mid-1700s. One of the earliest references to the use of paper for packaging is in 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). For an extensive summary of packaging from the 1400s using paper bags, labels, wrappers and cartons, see Davis, 1967.

The use of paper and paperboard packaging accelerated during the latter part of the nineteenth century to meet the developing 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 and components and in mechanising the packaging operation.

Today, examples of the use of paper and paperboard packaging are found in many places, such as supermarkets, traditional street markets, shops and departmental stores, as well as for mail order, fast food, dispensing machines, pharmacies, and in hospital, catering, military, educational, sport and leisure situations.

For example, uses can be found for the packaging of:

- dry food products – e.g. cereals, biscuits, bread and baked products, tea, coffee, sugar, flour, dry food mixes
- frozen foods, chilled foods and ice cream
- liquid foods and beverages – milk, wines, spirits
- chocolate and sugar confectionery
- fast foods
- fresh produce – fruits, vegetables, meat and fish
- personal care and hygiene – perfumes, cosmetics, toiletries
- pharmaceuticals and health care
- sport and leisure
- engineering, electrical and DIY
- agriculture, horticulture and gardening
- military stores.

Papers and paperboards are sheet materials comprising an intertwined network of cellulose fibres. They are printable and have physical properties which enable them to be made into various types of flexible, semi-rigid and rigid packaging.

There are many different types of paper and paperboard. Appearance, strength and many other properties can be varied depending on the type(s) and amount of fibre used, and how the fibres are processed in fibre separation (pulping), fibre treatment and in paper and paperboard manufacture.

In addition to the type of paper or paperboard, the material is also characterised by its weight per unit area and thickness.

The papermaking industry has many specific terms and a good example is the terminology used to describe weight per unit area and thickness.

Weight per unit area may be described as ‘grammage’ because it is measured in grammes per square metre ($g/m^2$). Other area/weight related terms are ‘basis weight’ and ‘substance’ which are usually based on the weight in pounds of a stated number of sheets of specified dimensions, also known as a ‘ream’, for example 500 sheets of 24 in. × 36 in., which equates to total ream area of 3000 sq ft. Alternative units of measurement used in some parts of the industry would be pounds per 1000 square feet or pounds per 2000 square feet. It is therefore important when discussing

weight per unit area, as with all properties, to be clear as to the methods and units of measurement.

Thickness, also described as 'caliper', is measured either in microns (μm), 0.001 mm or in thou. (0.001 in.), also referred to as *points*.

Appearance is characterised by the colour and surface characteristics, such as whether it has a high gloss, satin or matte 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 Organization for Standardization) as paperboard, board or cardboard. Some products are, however, known as paperboard even though they are manufactured in grammages less than 200 g $m^{-2}$ and, on the other hand, CEPI, the Confederation of European Paper Industries, states, 'paper is usually called board when it is heavier than 220 g $m^{-2}$'.

The main types of paper and paperboard-based packaging are:

- bags, wrappings and infusible tissues, for example tea and coffee bags, sachets, pouches, overwraps, sugar and flour bags, carrier bags
- multiwall paper sacks
- folding cartons and rigid boxes
- corrugated and solid fibreboard boxes (transit or 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-based packaging is widely used because it meets the criteria for successful packing, namely to:

- contain the product
- protect goods from mechanical damage
- preserve products from deterioration
- inform the customer/consumer
- provide visual impact through graphical and structural designs.

These needs are met at all three levels of packaging, namely:

- primary – product in single units at the point of sale or use, for example cartons
- secondary – groups of primary packs packed for storage and distribution, wholesaling and 'cash and carry', for example transit trays and cases
- tertiary – unit loads for distribution in bulk, for example heavy-duty fibreboard packaging.

Paper and paperboard, in many packaging forms, meet these needs because they have appearance and performance properties which enable them to be made into a wide range of packaging structures cost-effectively.

They are printable, varnishable and can be laminated to other materials. They have physical properties which enable them to be made into flexible, semi-rigid and rigid packages by cutting, creasing, folding, forming, winding, gluing, etc.

Paper and paperboard packaging is used over a wide temperature range, from frozen-food storage to the temperatures of boiling water and heating in microwave and conventional 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 papers), gases such as oxygen, carbon dioxide and nitrogen, aggressive chemicals and volatile vapours and aromas. Whilst paper and paperboard can be sealed with several types of adhesive, it is not itself heat sealable.

Paper and paperboard can acquire barrier properties and extended functional performance, such as heat sealability, heat resistance, grease resistance, product release, etc. by coating, lamination and impregnation. Materials used for these purposes in these ways include extrusion coating with polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET or PETE), ethylene vinyl alcohol (EVOH) and polymethyl pentene (PMP); lamination with plastic films or aluminium foil; and by treatment with wax, silicone or fluorocarbon. Papers can be impregnated with a vapour-phase metal-corrosion inhibitor, mould inhibitor or coated with an insect repellent.

Packaging made solely from paperboard can also provide a wide range of barrier properties by being *overwrapped* with a heat-sealable plastic film, such as polyvinylidene chloride (PVdC) coated oriented polypropylene (OPP or as it is sometimes referred to BOPP).

Several types of paper and paperboard-based packaging may incorporate metal or plastic components, examples being as closures in liquid-packaging cartons and as lids, dispensers and bases in composite cans.

In an age where environmental and waste management issues have a high profile, packaging based on paper and paperboard has important advantages that:

- The main raw material (wood) is based on a naturally renewable resource, the growth of which removes carbon dioxide from the atmosphere, thereby reducing the greenhouse effect.
- When the use of the package is completed, many types of paper and paperboard packaging can be recovered and recycled. They can also be incinerated with energy recovery and if none of these options is possible, they are biodegradable in landfill.

## 1.2 Choice of raw materials and manufacture of paper and paperboard

### *1.2.1 Introduction to raw materials and processing*

So far we have indicated that paper and paperboard-based packaging provides a well-established choice for meeting the packaging needs of a wide range of

products. We have defined paper and paperboard and summarised the reasons why this type of packaging is used. We now need to discuss the underlying reasons why paper and paperboard packaging is able to meet these needs.

This discussion falls into four distinct sections:

- choice and processing of raw materials
- manufacture of paper and paperboard
- additional processes which enhance the appearance and performance of paper and paperboard by coating and lamination
- use of paper and paperboard in the printing, conversion and construction of particular types of packaging.

Cotton, wool and flax are examples of fibres and we know that they can be spun into a thread and that thread can be woven into a sheet of cloth material. Papers and paperboards are also based on fibre, but the sheet is a three-dimensional structure formed by a random intertwining of fibres. The resulting structure, which is known as a *sheet* or *web*, is sometimes described as being 'non-woven'. The fibres are prepared by mixing them with water to form a very dilute suspension, which is poured on to a moving wire mesh. The paper structure is formed as an even layer on the wire mesh, which acts as a sieve. Most of the water is then removed successively by drainage, pressure and heat.

So why does this structure have the strength and toughness which makes it suitable for printing and conversion for use in many applications, including packaging? To answer this question we need to examine the choices which are available in the raw materials used and how they are processed.

According to tradition, paper was first made in China around the year AD 105 using fibres such as cotton and flax. Such fibres are of vegetable origin, based on cellulose, which is a natural polymer, formed in green plants from carbon dioxide and water by the action of sunlight. The process initially results in natural sugars based on a multiple-glucose-type structure comprising carbon, hydrogen and oxygen in long chains of hexagonally linked carbon atoms, to which hydrogen atoms and hydroxyl (OH) groups are attached. This process is known as photosynthesis, oxygen is the by-product and the result is that carbon is removed (fixed) from the atmosphere. Large numbers of cellulose molecules form fibres – the length, shape and thickness of which vary depending on the plant species concerned. Pure cellulose is non-toxic, tasteless and odourless.

The fibres can bond at points of interfibre contact as the fibre structure dries during water removal. It is thought that bonds are formed between hydrogen (H) and hydroxyl (OH) units in adjacent cellulose molecules causing a consolidation of the three-dimensional sheet structure. The degree of bonding, which prevents the sheet from fragmenting, depends on a number of factors which can be controlled by the choice and treatment of the fibre prior to forming the sheet.

The resulting non-woven structure which we know as paper ultimately depends on a three-dimensional intertwined fibre network and the degree of interfibre bonding. Its thickness, weight per unit area and strength can be controlled, and