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1.1 Learning Objectives

This module has been written to provide a basic understanding of and introduction to food packaging. On completion of this introductory module, the student will be familiar with the functions and attributes of food packaging, together with the environments where packaging has to perform those functions. Subsequent modules will provide an introduction to the four major groups of food packaging materials: paper-based materials; metals; glass and plastics. The last module concludes with a brief consideration of closures and heat sealing.

1.2 Background

Packaging is so familiar in everyday life that we tend to take it for granted. It is not until we try and open a package and experience difficulties, or have consumed the product and then need to dispose of the used packaging that it becomes a topic of conversation. In other words, it is largely only the negative aspects of packaging that come to the attention of the average consumer. As a consequence, packaging is often regarded as unnecessary and wasteful of resources, when in reality it is essential in delivering safe, high quality food to billions of consumers every day.

Insufficient food is still a major problem for many of those living in developing countries. While there is no single solution, United Nations studies have indicated that up to 50% of the food that is produced in developing countries never reaches the consumer because it becomes spoiled, is lost during transportation or is eaten or infested by insects and rodents. Much of this loss could be prevented or minimized by good packaging. Therefore to address global food poverty, more and better packaging is needed, and it is hoped that these modules will contribute to alleviating poverty and ensuring that more of the food which is produced reaches the final consumer.

1.2.1 Definition of Packaging

Food packaging is essential and pervasive: essential since without packaging the safety and quality of food would be compromised; and pervasive since almost all food is packaged in some way. Food packaging performs a number of disparate tasks. It protects the food from contamination and spoilage; it makes it easier to transport and store foods; and it provides uniform measuring of contents. By allowing brands to be created and standardized, it makes advertising
meaningful and large-scale
distribution and mass merchandising
possible. Food packages with
dispensing caps, sprays, reclosable
openings and other features make
products more usable and convenient.

Packaging has been defined as a socio-
scientific discipline which ensures
delivery of goods to the ultimate
consumer of those goods in the best
condition appropriate for their use.
Packaging has also been defined as the
enclosure of products, items or
packages in a wrapped pouch, bag,
box, cup, tray, can, tube, bottle or
other container form to perform one
or more of the following functions:
containment; protection and/or
preservation; communications; and
utility or performance. If the device
or container performs one or more of
these functions it is considered a
package.

Other definitions of packaging include
a coordinated system of preparing
goods for transport, distribution,
storage, retailing and end-use; a
means of ensuring safe delivery to the
ultimate consumer in sound condition
at optimum cost; and a techno-
commercial function aimed at
optimizing the costs of delivery while
maximizing sales (and hence profits).

It is important to distinguish between
the words package, packaging and
packing. The package is the physical
entity that contains the product.
Packaging was defined above and in
addition is also a discipline (e.g.,
packaging technology) and a job title
(e.g., Packaging Technologist). The
verb ‘packing’ involves the enclosure
of products in a package such as a
pouch, bag, box, cup, tray, can, tube,
bottle or other container to perform
one or more of the following
functions: containment; protection;
convenience and communications.

A distinction is usually made between
the various ‘levels’ of packaging. A
primary package is one which is in
direct contact with the contained
product. It provides the initial and
usually the major protective barrier.
Examples of primary packages include
metal cans, paperboard cartons, glass
bottles and plastic pouches. It is
frequently only the primary package
which the consumer purchases at
retail outlets. A secondary package
contains a number of primary
packages, e.g. a corrugated case or
box. It is the physical distribution
carrier and is sometimes designed so
that it can be used in retail outlets for
the display of primary packages. A
tertiary package is made up of a
number of secondary packages, the
most common example being a
stretch-wrapped pallet of corrugated
cases. This module will confine itself
largely to a consideration of the
primary package.

Corrugated boxes are the most
common type of secondary package
1.2.2 Historical Development

In many respects the history of packaging is the history of civilization since as soon as people needed to carry and contain food, they needed a package. Initially gourds, leaves and shells were used, as well as animal skins and bladders, as food containers. After pottery evolved in 6000 BC, it became widely used as a container or package. Glass was first manufactured as far back as 3000 BC but its production was time consuming and therefore only expensive products.

Increasingly supermarkets are requiring shelf-ready packaging as in this example of a corrugated box where the lid can be removed and the whole box put on the shelf.

Another example of shelf-ready packaging; without the secondary package it would be almost impossible to display the tubes of tomato puree on the shelf.
such as perfumes were packaged in glass. Then around 100 BC, a method of glass blowing was discovered and this significantly lowered the cost of glass containers leading to their widespread use as containers.

In early times food was consumed where it was found. With the development of agriculture, families and villages were self-sufficient, producing, making and catching what they used. When packaging was needed, nature provided shells, gourds, animal skins, etc. In time, containers or packaging were made from natural materials such as reeds, grasses, logs, bark and animal parts. Grasses and reeds were woven into baskets to store food. As ores and metals were discovered, metals and pottery were developed, leading to other packaging forms.

Although glassmaking began in 7000 B.C. as an offshoot of pottery, it was first industrialized in Egypt in 1500 B.C. When the blowpipe was invented by the Phoenicians in 300 B.C., it not only speeded production but allowed for round containers. The split mold developed in the 17th and 18th centuries further provided for irregular shapes and raised decorations. One development that enhanced the process was the first automatic rotary bottle-making machine, patented in 1889. Current equipment automatically produces 20,000 bottles per day.

The use of materials other than pottery and glass for packaging centered around leather bags, wooden barrels and metals. Around 1200 AD the hot-dip process for coating thin sheets of steel with tin to manufacture tinplate was developed although it would not be until the mid-1800s that the tinplate can came into widespread use for canned foods.

Papermaking has been attributed to Ts’ai-Lun of China in 105 AD. Sheets of treated bamboo and mulberry bark were used by the Chinese to wrap foods. During the next fifteen hundred years, the papermaking technique was refined and transported to the Middle East, then Europe and finally into the United Kingdom in 1310. The technique arrived in America in Germantown, Pennsylvania, in 1690.

Corrugated paperboard appeared in the 1850s; about 1900, shipping cartons of faced corrugated paperboard began to replace self-made wooden crates and boxes.

A brief sequence of the most important developments in packaging is listed below:

1795: Napoleon offers a prize of 12,000 francs for a food preservation technique which is won by French confectioner Nicolas Appert who heated food in glass bottles closed with corks for several hours in boiling water – the forerunner of modern canning.
1810: French engineer and inventor Phillipe de Girard introduced the tinplate can in England; Peter Durand acting as Girard’s agent patented the process in England. Cans had to be closed by soldering.

1871: Jones receives first US patent for corrugated paperboard.

1899: Development of double seam for metal cans renders soldering obsolete and makes high speed food production feasible.

1899: William Painter patents crown seal for glass bottles.
1903: First fully automatic glass bottle-blowing machine in Toledo, USA.

1906: Paperboard cartons first used on a large scale by Kellogg in the USA.

1912: First aseptic food packaging system (for milk in tinplate cans)) described by Nielsen in Denmark.

1914: Josef Jönsson from Sweden introduced aluminum foil cap for glass milk bottles.

1915: Wax-coated, liquid-tight, gabletop carton for milk patented in the USA by John Van Wormer.
1935: Swiss chemist Brandenberger produces regenerated cellulose film which he names cellophane.

1927: Waldo Semon at BF Goodrich developed a method to plasticize PVC (polyvinyl chloride) by blending it with various additives. The result was a more flexible and more easily processed material that soon achieved widespread commercial use.

1933: Polyethylene discovered by Reginald Gibson and Eric Fawcett at the British industrial giant Imperial Chemical Industries (ICI).

1929: Jagenberg Werke AG in Dusseldorf, Germany patented a wax-coated, liquid-tight carton (the Perga system).

1935: The polyamide nylon 6,6 is synthesized by Wallace Carothers and coworkers at Du Pont.
1937: McManus perfects the electrolytic tinplating process and introduces the Crowntainer. This 2-piece drawn, necked-in steel can sealed with a crown is introduced in the USA as a quart beer can for Schmidt’s. Schiltz used the cone top can manufactured by the Continental Can Company for beer from the 1930s until the early 1950s.

1937: Molded pulp egg trays designed (Hartman) patented in Europe.

1938: Cliquot Club ginger ale was the first canned soft drink in a cone top can produced by Continental Can Company.

1939: Production of the polyamide nylon 6,6 by Du Pont.

1950: First two-piece (impact extruded) aluminum beer can produced in Switzerland.

1951: Original tetrahedron paperboard carton manufactured by Tetra Pak.


1956: Tetra Pak begins coating paperboard cartons with low density polyethylene supplied by Du Pont.

1960: Easy-opening can was introduced.
1961: Tetra Pak launches aseptic carton for milk in Switzerland.


1963: First aluminum beverage can was manufactured by Reynolds Metals Company and used to package a diet cola called "Slenderella".

1964: DWI (Drawn and Wall Ironed) two-piece aluminum can for beer developed.

1965: Ring-pull easy open end for beverage cans developed by Ermal Fraze in the USA is launched.

1968: Dow Chemical introduces ZIPLOC® food storage bags to consumers.

1969: Tetra Pak launches the brick-shaped Tetra Brik Aseptic carton.

1969: Crown introduces the Drawn-N-Ironed (DWI), two-piece steel beverage can as an alternative to the aluminum can.
1969: Commercial production of retortable plastic/alufoil pouch.

1970: Ethylene vinyl alcohol (EVOH) copolymer released by Kuraray Company in Japan. First major use was as an oxygen barrier layer in the squeezable ketchup bottle.

1971: Mitsubishi Gas Chemical (MGC) in Japan begin production of the polyamide MXD6 which has better gas barrier properties than EVOH at high humidities.

1973: Nathaniel Wyeth (below) and Ronald Roseveare from Du Pont file patent for biaxially oriented polyethylene terephthalate (PET) bottle.

1975: Stay-on easy open tab for beer cans invented by Daniel Cudzik of Reynolds Metals in USA. Stay tabs almost completely replaced pull-tabs by the early 1980s, helping to prevent the injuries and litter caused by removable tabs.

1972: First ‘widget’ beer-foaming device manufactured for Guinness.
1977: Polyethylene terephthalate (PET) bottle launched for carbonated soft drinks.

1978: Development of the SUPERWIMA welding process for can side seams by Soudronic AG in Switzerland.


Comparative Flute Heights

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1985: Sanko Machinery Co., Ltd in Japan develops the stick pack.

2000: Shaped metal cans launched.

2000: Bottles manufactured from aluminum are launched.

2002: Launch of retortable laminated paperboard carton (Tetra Recart) by Tetra Pak.

2005: Launch of PLA (polylactic acid) plastic made from corn.
2008: Reclosable can end for carbonated drinks released by Ball Corporation in Europe.

2009: Launch of polyhydroxyalkanoate (PHA) biodegradable plastic made from corn.
1.3 Functions of Packaging

Four primary and inter-connected functions of packaging have been identified: containment, protection, convenience and communication.

1.3.1. Containment

This function of packaging is so obvious as to be overlooked by many, but it is the most basic function of packaging. Food products must be contained before they can be moved from one place to another. The containment function of packaging makes a huge contribution to preventing losses from the myriad of foods which are moved from one place to another on numerous occasions each day.

Freedom from harmful microbial contaminants at the time of consumption can also be influenced by the package. Firstly, if the packaging material does not provide a suitable barrier around the food, microorganisms can contaminate the food and make it unsafe. Microbial contamination can also arise if the packaging material permits the transfer of, for example, moisture or oxygen from the atmosphere into the package. In this situation, microorganisms present in the food but presenting no risk because of the initial absence of moisture or oxygen may then be able to grow and present a risk to the consumer.

1.3.2. Protection

This is often regarded as the primary function of the package: to protect its contents from outside environmental effects, be they water, water vapor, gases, odors, microorganisms, dust, shocks, vibrations, compressive forces, etc., and to protect the environment from the product.

For the majority of food products, the protection afforded by the package is an essential part of the preservation process. For example, aseptically packaged milk in paperboard laminate cartons only remains aseptic for as long as the package provides protection; vacuum-packaged meat will not achieve its desired shelf life if the package permits oxygen to enter. In general, once the integrity of the package is breached, the product is no longer preserved.
Packaging also protects or conserves much of the energy expended during the production and processing of the product. For example, to produce, transport, sell and store 1 kg of bread requires 15.8 MJ (megajoules) of energy. This energy is required in the form of transport fuel, heat, power and refrigeration in farming and milling the wheat, baking and retailing the bread, and in distributing both the raw materials and the finished product. To produce the polyethylene bag to package a 1 kg loaf of bread requires 1.4 MJ of energy. This means that each unit of energy in the packaging protects eleven units of energy in the product. While eliminating the packaging might save 1.4 MJ of energy, it would also lead to spoilage of the bread and a consequent waste of 15.8 MJ of energy.

1.3.3. Convenience

Modern industrialized societies have brought about tremendous changes in life styles and the packaging industry has had to respond to those changes which have created a demand for greater convenience in household products: foods which are pre-prepared and can be cooked or reheated in a very short time, preferably without removing them from the package; condiments that can be applied simply or pump-action packages; dispensers for sauces or dressings which minimize mess; reclosable openings on drink bottles to permit consumption on the go, etc. Thus packaging plays an important role in allowing products to be used conveniently.

Two other aspects of convenience are important in package design. One of these can best be described as the
Introduction to Food Packaging

1.3.4. Communication

There is an old saying that ‘a package must protect what it sells and sell what it protects’, i.e., the package functions as a ‘silent salesman’. The modern methods of consumer marketing would fail were it not for the messages communicated by the package through distinctive branding and labeling, enabling supermarkets to function on a self-service basis. Consumers make purchasing decisions using the numerous clues provided by the graphics and the distinctive shapes of the packaging.

Other communication functions of the package include a UPC (Universal Product Code) that can be read accurately and rapidly using modern scanning equipment at retail checkouts, and nutritional information on the outside of food packages which has become mandatory in many countries.

Anatomy of a UPC Barcode
1.4 Attributes of Packaging

There are also several attributes of packaging that are important.

1.4.1 Commercially Efficient

One (related to the convenience function) is that it should be efficient from a production or commercial viewpoint, i.e. in filling, closing, handling, transportation and storage.

1.4.2 Minimal Environmental Impacts

Another is that the package should have, throughout its life cycle from raw material extraction to final disposal after use, minimal negative environmental impacts.

1.4.3 Not Contaminate Food

A third attribute is that the package should not impart to the food any undesirable contaminants. Although this last attribute may seem self-evident, there has been a long history of so-called food contact substances migrating from the packaging material into the food. For many years the solder used in three-piece metal cans resulted in lead migrating into some foods; the switch to welded side seams eliminated this source of lead. Plasticizers have also migrated into foods, e.g. phthalates, as well as monomers, e.g. styrene monomer, catalysts, e.g. antimony from PET bottles and photoinitiators from printing inks, e.g. ITX. Not surprisingly, food packaging materials are highly regulated to ensure consumer safety.

1.5 Environments of Packaging

The packaging has to perform its functions in three different environments. Failure to consider all three environments during package development will result in poorly designed packages, increased costs, consumer complaints and even avoidance or rejection of the product by the customer.

1.5.1 Physical

This is the environment in which physical damage can be caused to the product. It includes shocks from drops, falls and bumps; damage from vibrations arising from transportation modes including road, rail, sea and air;
and compression and crushing damage arising from stacking during transportation or storage in warehouses, retail outlets and the home environment.

1.5.2 Atmospheric

This is the environment which surrounds the package. Damage to the product can be caused as a result of gases (particularly oxygen), exhaust fumes, water and water vapor, light (particularly UV radiation), and the effects of heat and cold, as well as microorganisms (bacteria, fungi, molds, yeasts and viruses) and macroorganisms (rodents, insects, mites and birds) which are ubiquitous in many warehouses and retail outlets. Contaminants in the ambient environment such as exhaust fumes from automobiles and dust and dirt can also find their way into the product unless the package acts as an effective barrier.

1.5.3 Human

This is the environment in which the package interacts with people, and designing packages for this environment requires knowledge of the human strengths and frailties of vision, strength, weakness, dexterity, memory, cognitive behavior, etc. It also includes results of human activity such as liability, litigation, legislation and regulation. Since one of the functions of the package is to communicate, it is important that the messages are received clearly by consumers. In addition, the package must contain information required by law such as nutritional content and net weight. To maximize its convenience or utility functions, the package should be simple to hold, open, use and (if appropriate) reclose by the consumer.
Consumers often complain about the difficulty they experience in opening or accessing packages. Older consumers generally experience more problems than younger consumers, due in large part to the loss of strength as people get older. For example, the grip strength (a measure of the force required undo a cap on a bottle or remove a metal cap on a glass jar) peaks at around 25-39 years for men and women and then declines. The maximum grip strength for men is about 120 pounds, declining to 90 pounds for men aged 60-64 and 75 pounds for men over 70. With an increasing proportion of the population living longer and often alone, packaging manufacturers need to consider this decline in strength with age.

Contributing to the difficulty in opening packages is the trend for more tamper-evident packaging, i.e. a feature on the package which indicates if the package has been tampered with or accessed. The most common form of tamper evidence on a closure is a plastic sleeve which must be breached before the closure can be removed. More sophisticated tamper evident devices use holograms.

1.6 Functions/Environments Grid

The functions of packaging and the environments where the package has to perform can be laid out in a two-way matrix or grid as shown in Figure 1. Everything that is done in packaging can be classified and located in one or more of the 12 function/environment cells. The grid provides a methodical yet simple way of evaluating the suitability of a particular package design before it is actually adopted and put into use. As well, the grid serves as a useful aid when evaluating existing packages including those used by your competitor.

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<tr>
<th>Physical</th>
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<th>Human</th>
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<td>Containment</td>
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<td>Communication</td>
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1.7 Food Packaging Materials

The materials used to manufacture food packaging consist of a heterogeneous group including glass, metals, plastics and paper with a corresponding range of performance characteristics.

In the selection of suitable packaging materials for a particular food, the focus is typically on the barrier properties of the packaging material. Foods can be classified according to the degree of protection required such as the maximum moisture gain or $O_2$ uptake. Calculations can then be made to determine whether or not a particular packaging material would provide the necessary barrier required to give the desired product shelf life.

Metal cans and glass containers can be regarded as essentially impermeable to the passage of gases, odors and water vapor provided that a metal end has been correctly seamed on in the case of cans or a satisfactory closure applied in the case of glass containers. Aluminum foil has excellent barrier properties provided that it is at least 25 μm thick; below this thickness the likelihood of pinholes increases. It is common to laminate plastic polymers to aluminum foil to provide mechanical support and heat sealability.

Paper-based packaging materials can be regarded as permeable and for this reason are normally coated with a plastic polymer to ensure adequate barrier properties for the packaging of foods. This then leaves plastics-based packaging materials which provide varying degrees of protection, depending largely on the nature of the polymers used in their manufacture.

1.8 Food Deterioration

Before suitable packaging can be selected, it is necessary to know how the food deteriorates because in some (but not all) cases, packaging can minimize or slow down the deteriorative reactions.

Foods are frequently classified on the basis of their stability as non-perishable, semi-perishable and perishable. An example of the first classification is sugar; provided it is kept dry, at ambient temperature and free from contamination, it should have a very long shelf life. However, few foods are truly nonperishable, and an important factor influencing their perishability is the packaging.
For example, hermetically sealed and heat processed (e.g. canned) foods are generally regarded as nonperishable. However, they may become perishable under certain circumstances, e.g. if the can seams are faulty, or if there is excessive corrosion resulting in internal gas formation and eventual bursting of the can.

Foods with low moisture content such as dried fruits and vegetables, and baked goods are classified as semi-perishable.

Frozen foods, though basically perishable, may be classified as semi-perishable provided that they are properly stored at freezer temperatures.

The majority of foods (e.g. flesh foods such as meat and fish; milk, eggs and most fruits and vegetables) are classified as perishable unless they have been processed in some way. Often, the only form of processing which such foods receive is to be packaged and kept under controlled temperature conditions.
1.9 Conclusions

Knowledge of the functions of packaging and the environments where it has to perform will lead to the optimization of package design and the development of real, cost-effective packaging.

Despite the number of functions which a package must perform, this module focuses almost exclusively on the protective functions of the primary package and possible food/package interactions in relation to the ambient environment. Package performance in the physical environment is usually considered under the heading of packaging engineering. The communication function of package performance in the human environment is properly the major concern of those with a primary interest in marketing and advertising, and there are many books that deal specifically with this aspect. For those focusing on the convenience-in-use aspects of packaging, books in the area of consumer ergonomics are the best source of information.
CHAPTER 2: PAPER-BASED PACKAGING

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2.8.5 Corrugated Cartons
2.8.6 Solid Fiberboard
2.1 Learning Objectives

This module has been written to provide a basic understanding of, and introduction to, paper-based packaging materials. On completion of this module, the student will have a general appreciation of the raw materials and processes used to manufacture paper-based packaging materials, as well as the major categories of paper-based packaging materials and their use in the packaging of food.

2.2 Introduction

Paper derives its name from the reedy plant *papyrus* which the ancient Egyptians used to produce the world's first writing material by beating and pressing together thin layers of the plant stem. However, complete defibering which is characteristic of true papermaking was absent. The first authentic papermaking, which is the formation of a cohesive sheet from the rebonding of separated fibers, has been attributed to Ts'ai-Lun of China in 105 AD, who used bamboo, mulberry bark and rags. Since then many fibers have been used for the manufacture of paper including those from flax, bamboo and other grasses, various leaves, cottonseed hair, old linen rags and the woody fibers of trees. It was not until 1867 that paper originating from wood pulp was developed.

Although paper is the general term for a wide range of matted or felted webs of vegetable fiber that have been formed on a screen from a water suspension, it is usually subdivided into paper and paperboard. However, there is no rigid line of demarcation between the two, with structures <300 µm (micron) thick being considered paper regardless of the grammage or weight per unit area. ISO standards define paperboard as paper with a basis weight (grammage) generally above 224 gsm (grams per square meter) but there are exceptions.

2.3 Raw Material

Pulp is the fibrous raw material for the production of paper, paperboard, corrugated board and similar manufactured products. It is obtained from plant fiber and is therefore a renewable resource. Today about 97% of the world's paper and board is made from wood pulp, and about 85% of the wood pulp used is from spruces, firs and pines – coniferous, softwood trees that predominate in the forests of the north temperate zone (so-called taiga or boreal forests). These forests cover vast areas of North America from the Pacific to the Atlantic, and range across northern Europe, Scandinavia, Russia and across Asia through Siberia and Mongolia to northern China and northern Japan;
some are found in the southern hemisphere. Coniferous forests are made up mainly of cone-bearing trees and their leaves are either small and needle-like or scale-like and most stay green all year around (evergreen). All are softwoods able to survive cold temperatures and acidic soil. Softwood trees have long fibers (typically 3 mm) and produce paper with good strength.

Deciduous trees lose their leaves seasonally and include species such as maple, many oaks, elm, aspen and birch. Temperate deciduous forests are distributed in America, Asia and Europe. They have formed under climatic conditions which have great seasonal temperature variability with growth occurring during warm summers and leaf drop in fall and dormancy during cold winters. Tropical and subtropical deciduous forests have developed in response not to seasonal temperature variations but to seasonal rainfall patterns. During prolonged dry periods the foliage is dropped to conserve water and prevent death from drought.

Softwood trees such as pine and spruce have wood with long fibers, and paper made from this type of wood is much stronger. This paper is ideal for making products like shipping containers that require superior strength. But the finish is rougher, and that's not as good for writing, printing and many other uses. Hardwood trees such as oaks and maples have wood with very short fibers. Paper made from these species is weaker than that made from softwoods, but its surface is smoother, and therefore better to write and print on.

There are three main constituents of the wood cell wall:

a. **Cellulose** - a long chain, linear polymer built up of a large number of glucose molecules; it is the most abundant, naturally-occurring organic compound. The fiber-forming properties of cellulose depend on the fact that it consists of long, relatively straight chains that tend to lie parallel to one another.

b. **Hemicelluloses** - these are lower molecular weight mixed-sugar polysaccharides and their quantity rather than their chemical nature determines the paper properties. Hemicellulose consists of shorter chains - 500-3000 sugar units as opposed to 7,000 - 15,000 glucose molecules per polymer seen in cellulose. In addition, hemicellulose is
a branched polymer, while cellulose is unbranched. Its presence aids the swelling of the pulp, the bonding of the fibers and strength properties.

c. Lignin - this is the natural binding constituent of the cells of wood, acting as a glue to bind the cellulose fibers together. It has no fiber-forming properties but makes wood stiff and trees stand upright. Exposure of lignin to air and sunlight is what turns paper yellow. Paper manufacturers utilize the benefits of lignin in some types of paper such as brown kraft paper, the brown paper used in grocery store bags, and cardboard. All of these are stiff and sturdy because they have more lignin in them, and because those kinds of paper are not treated with bleaching chemicals. It does not matter how dark they are because the printing on them is limited.

The cell wall of softwoods, which are preferred for most pulp products, typically contain 40-44% cellulose, 25-29% hemicelluloses and 25-31% lignin by weight. Compared to hardwoods, softwoods have fibers which are generally up to 2.5 times longer. As a result, hardwoods produce a finer, smoother but less strong sheet.

### 2.4 Pulping

The purpose of pulping is to separate the fibers without damaging them so that they can then be reformed into a paper sheet in the papermaking process. The intercellular substances (primarily lignin) must be softened or dissolved to free individual fibers. Commercial pulping methods take advantage of the differences between the properties of cellulose and lignin in order to separate fibers, but breaking and weakening of the fibers does occur to a greater or lesser degree at various stages during the pulping process.

Pulps that retain most of the wood lignin consist of stiff fibers that do not produce strong papers; they deteriorate in color and strength quite rapidly. These properties can be improved by removing most or all of the lignin by cooking wood with solutions of various chemicals, the pulps so produced being known as chemical pulps. In contrast, mechanical pulps are produced by pressing logs on to a grindstone, when the heat generated by friction softens the lignin so that the fibers separate with very little damage. Mechanical pulps can also be formed by grinding wood chips between two rotating refiner plates. In addition, there are some processes which are categorized as semi-chemical and chemi-mechanical.

#### 2.4.1 Mechanical Pulps

Groundwood pulp is produced by forcing wood against a rapidly revolving grindstone. Practically all the wood fiber (both cellulose and lignin) is utilized compared to the several
chemical processes where the lignin is dissolved to varying degrees. As a result, the yield of chemical pulp is about one half that of the mechanical process. The fibers vary in length and composition since they are in effect torn from the pulpwood.

Groundwood pulp contains a considerable proportion (70-80%) of fiber bundles, broken fibers, and fines in addition to the individual fibers. The fibers are essentially wood with the original cell-wall lignin intact. Therefore, they are very stiff and bulky, and do not collapse like the chemical pulp fibers.

Pressurized stone groundwood process

Most groundwood pulp is used in the manufacture of newsprint and magazine papers because of its low cost and quick ink absorbing properties (a consequence of the frayed and broken fibers). It is also used as board for folding cartons and molded containers, tissues and similar products. The paper has high bulk and excellent opacity, but relatively low mechanical strength.

Thermomechanical pulping (TMP) presteams chips to 110-150°C so that they become malleable and do not fracture readily under the impact of the refiner bars. This material is highly flexible and gives good bonding and surface smoothing to the paper. The production of TMP pulps increased dramatically after its introduction in the early 1970s because they could be substituted for conventional groundwood pulps in newsprint blends to give a stronger paper.

Chemithermomechanical pulping (CTMP) increases the strength properties of TMP pulps even further by a comparatively mild chemical treatment followed by pressurized refining. In general, CTMP pulps have a greater long fiber fraction and lower fines fraction than comparable TMP pulps. CTMP is suitable for the middle layer of multiply boards where it adds bulk and rigidity (stiffness) at lower cost than kraft pulp.

2.4.2 Chemical Pulps

There are several chemical pulping methods, each based either directly or indirectly on the use of sodium hydroxide. The objective is to degrade and dissolve away the lignin to allow the fibers to separate with little, if any, mechanical action. The nature of the pulping chemicals influences the properties of the residual lignin and the residual carbohydrates. For
production of chemical pulps, the bark is removed and the logs passed through a chipper. The chipped wood is charged into a digester with the cooking chemicals, and the digestion carried out under pressure at the required temperature.

In 1879, German chemist Carl F. Dahl developed a method of pulping wood using sodium sulfate as the major chemical in the cooking liquor. The new sulfate process produced a much stronger pulp which is more commonly known as kraft pulp after the German and Swedish word for strength. Today the sulfate process is the dominant chemical wood pulping process. The sulfate process has the ability to pulp any wood species, in particular pines, which are more resinous than firs and spruces and not easily pulped by the sulfite processes (see below).

There are also several pulping processes based on the use of sulfur dioxide as the essential component of the pulping liquor. These processes depend on the ability of sulfite solutions to render lignin partially soluble.

2.4.3 Semichemical Pulps

Semichemical pulping combines chemical and mechanical methods in which wood chips are partially softened or digested with conventional chemicals such as sodium hydroxide, sodium carbonate or sodium sulfate, after which the remainder of the pulping action is supplied mechanically, most often in disc refiners.

The object of this process is to produce as high a yield as possible commensurate with the best possible strength and cleanliness. The hemicelluloses, mostly lost in conventional chemical digestion processes, are retained to a greater
degree and result in an improvement in potential strength development. Semichemical pulps, although less flexible, resemble chemical pulps more than mechanical pulps.

2.4.4 Digestion

The digestion process consists essentially of the treatment of wood in chip form in a pressurized vessel under controlled conditions of time, liquor concentration and pressure/temperature. The main objectives of digestion are:

a. To produce a well-cooked pulp, free from the non-cellulosic portions of the wood, i.e. lignin and to a certain extent hemicelluloses;

b. To achieve a maximum yield of raw material, i.e. pulp from wood, commensurate with pulp quality;

c. To ensure a constant supply of pulp of the correct quality.

Today most pulping processes are continuous. After digestion, the liquor containing the soluble residue from the cook is washed out of the pulp which is then screened to remove knots and fiber bundles that have not fully disintegrated. The pulp is then sent to the bleach plant or paper mill.

2.4.5 Bleaching

Pulps vary considerably in their color after pulping, depending on the wood species, method of processing and extraneous components. Cellulose and hemicellulose are inherently white and do not contribute to color; it is the lignin that is largely responsible for the color of the pulp.

The dark color of the pulp is mainly due to residual lignin that is removed gradually during bleaching.

Basically there are two types of bleaching operations: those that chemically modify the colored bodies but remove very little lignin or other substances from the fibers, and those that complete the delignification process and remove some carbohydrate material.
reduces the strength of the pulp, it is necessary to reach a compromise between the brightness (a measure of reflected light) of the finished sheet and its tensile properties.

In 1986, the production process for bleached chemical pulp was identified as a major contributor of the carcinogens polychlorinated dioxins and dibenzofurans to the environment. Chlorine bleaching was identified as the major source of these compounds. Strict regulations now limit the production of these chlorinated compounds, resulting in a move away from molecular chlorine bleaching to chlorine dioxide (so-called ECF or elemental chlorine free bleaching) and to oxygen and peroxide (so-called TCF or total chlorine free bleaching). These changes have been introduced to enable pulp and paper mills to meet tough new anti-pollution laws and regulations and to conserve wood, chemicals and energy.

2.5 Paper

2.5.1 Stock Preparation

Stock preparation is the interface between the pulp mill and the papermaking process in which pulp is treated mechanically and, in some instances, chemically by the use of additives, and is thus made ready for forming into a sheet or board on the paper machine. During the stock preparation steps the pulps are most conveniently handled as aqueous slurries. However, papermaking processes that utilize purchased pulps and waste (recycled) paper which are received as dry sheets, the first step is the separation of all the fibers from one another, and their dispersion in water with a minimum of mechanical work to avoid altering the fiber properties. This process is known as slushing or repulping and is carried out in a machine such as the hydrapulper shown below, so-called because of the hydraulic forces which are developed. When the pulping and papermaking operations are adjacent to one another, pulps are usually delivered to the paper mill in slush form directly from the pulping operation.

![Inside view of a hyrapulper](image)

2.5.2 Beating, Refining and Sizing

Beating and refining are used to improve the strength and other physical properties of the finished sheet, and to influence the behavior of the system during the sheet-forming and drying steps. The object of beating is to increase the surface area of the fibers by assisting them to imbibe water. As a result additional bonding opportunities are provided for between cellulose molecules of neighboring fibers. The beating also makes the fibers more flexible, causing them to become relatively mobile and to deform plastically on the paper machine. The mixture of pulp (known as the furnish) is passed into the beater and brought to a consistency of 5-7%. The fibers are then beaten while suspended in the water in order to
impart to them many of the properties that will determine the character of the final product.

Sizing is the process of adding materials to the paper in order to render the sheet more resistant to penetration by liquids, particularly water and ink. Rosin is the most widely used sizing agent, but starches, glues, casein, synthetic resins and cellulose derivatives are also used.

2.5.3 Papermaking

Paper is made by depositing a very dilute suspension of fibers from a very low consistency aqueous suspension (greater than 99% water) on to a relatively fine woven screen, over 95% of the water being removed by drainage through the wire. The fibers interlace in a generally random manner as they are deposited on the wire and become part of the filter medium.

The modern fourdrinier paper machine consists essentially of an endless woven wire gauze or forming fabric stretched over rollers. The concentration of the fiber suspension delivered to the moving screen via a flow box is generally 0.4-1.2% and increases as a result of free drainage through the screen. Fibers tend to align in the direction of travel of the belt known as the machine direction (MD). The direction across the papermaking machine and therefore across the fiber alignment is known as the cross direction (CD) or sometimes the transverse direction (TD). Fiber alignment gives paper different properties in the MD and CD directions which must be taken into account when using the paper for packaging purposes. For example, paper tears easiest along the MD.

The fiber concentration increases to 3-4% further down the fourdrinier table where a vacuum is applied in the suction boxes. For the production of multiply paperboard, a secondary flow box is often used. Fourdrinier machines are standard in the industry and are used to produce all grades of paper and paperboard.

An alternative to the fourdrinier
The advantage of the cylinder machine for the manufacture of boards is that a number of cylinder units can be arranged so that the fiber mat from each is deposited as a layer and all the layers can be combined to make a multiply paperboard (see photo above).

The twin-wire former method for making paper and paperboard was developed in the UK in the 1950s. The paper web is formed between two converging forming screens by means of a flow box, and the water is drained from the slurry by pressure and later by vacuum. Successive layers of fiber are laid down sequentially on the felt, water being removed upwardly, overcoming the difficulty experienced in the conventional downward removal of water through several layers of board at high speed.

Twin-wire former

Twin-wire formers have replaced the fourdrinier wet-ends on many machines, particularly for lightweight sheets, corrugated media and linerboard grades.

After leaving the forming fabric of the papermaking machine, the sheet (which has a moisture content of 75-90%) passes to the press and drier sections for further water removal. On leaving the press the moisture content is typically 60-70%. The paper is then passed through a series of steam-heated rollers and dried to a final moisture content of 4-10%.

2.5.4 Converting

Almost all paper is converted by undergoing further treatment after manufacture, such as embossing, impregnating, saturating, laminating and the forming of special shapes and sizes such as bags and boxes. Further surface treatment involving the application of adhesives, functional products and pigments are common, depending on the end use of the paper. Because of the widespread use of paper and paperboard in direct contact with foods, most mills use
paper chemicals that have been cleared for use with food by regulatory authorities such as the FDA and the EU.

In many applications, the surface of the sheet needs improvement in order that any characters printed on the sheet are legible. This is achieved by calendering, a process which reorients the surface fibers in the base sheet of paper (or the coating applied to the surface) by the use of pressure. This serves to smooth the surface, control surface texture and develop a glossy finish. Such papers are known as ‘machine finished’ (MF).

Surface treatments such as sizing and coating are extensively applied to improve the appearance of products. Paper may be coated either on equipment that is an integral part of the paper machine (i.e. on-machine coating), or on separate converting equipment. The most common method for the application of chemicals to the surface of a paper web is with a size press where dry paper is passed through a flooded nip and a solution or dispersion of the functional chemical contacts both sides of the paper. Excess liquid is squeezed out in the press and the paper is redried.

Surface sizing agents prevent excess water penetration and improve the strength of the paper. The sizing agent penetrates far enough into the paper to increase the fiber bonding and the dependent properties such as bursting, tensile and folding strengths. An additional effect is an improvement in the scuffing resistance of the paper surface.

The most commonly used materials for surface sizing are starches. Fluorochemical emulsion sizing agents can be applied to the surface of paper or paperboard to provide good oil and grease repellancy. They find application for fast food packaging, pet food bag papers, meat, fish and poultry wraps, cookie bags and candy wrappers.

2.6 Physical Properties

Most properties of paper depend on direction. Paper has a definite grain caused by the greater orientation of fibers in the direction of travel of the paper machine, and the greater strength orientation that results partly from the greater fiber alignment and partly from the greater tension exerted on the paper in this direction during drying. The grain direction is known as the machine direction (MD), while the cross direction (CD) is the direction of the paper at right angles to the machine direction. The grain of paper must be taken into account in...
measuring all physical properties.

Papers vary in MD:CD strength ratios, with cylinder-machine papers having a higher ratio than fourdrinier papers, the latter values varying from about 1.5 to 2.5. Usually there is less variation in paper properties in the MD than in the CD because variations occur slowly in the MD whereas in the CD they may occur quite suddenly for a variety of process-related reasons. As well, the CD strength normally varies depending on how far the sample was taken from the edge of the sheet. In general, papers should be used to take the greatest advantage of the grain of the paper.

2.7 Types of Paper

Paper is divided into two broad categories: fine papers, generally made of bleached pulp, and typically used for writing paper, bond, ledger, book and cover papers, and coarse papers, generally made of unbleached kraft softwood pulps and used for packaging. Only the latter type will be discussed here.

2.7.1 Kraft Paper

This is typically a coarse paper with exceptional strength, often made on a fourdrinier machine and then machine-finished on a calender. It is sometimes made with no calendering so that when it is converted into multiwall bags, the rough surface will prevent them from sliding over one another when stacked on pallets.
difficult. However, they are not strictly ‘greaseproof’ since oils and fats will penetrate them after a certain interval of time. Despite this, they are often used for packaging butter and similar fatty foods since they resist the penetration of fat for a reasonable period.

2.7.4 Glassine Paper

Glassine paper derives its name from its glassy, smooth surface, high density and transparency. It is produced by further treating greaseproof paper in a supercalender where is it carefully dampened with water and run through a battery of steam-heated rollers. The transparency can vary widely depending on the degree of hydration of the pulp and the basis weight of the paper. The addition of titanium dioxide makes the paper opaque, and it is frequently plasticized to increase its toughness.

2.7.5 Vegetable Parchment

Vegetable parchment takes its name from its physical similarity to animal parchment (vellum) which is made from animal skins. The process for producing parchment involves passing a web of high quality, unsized chemical pulp through a bath of concentrated sulfuric acid. The cellulosic fibers swell and partially dissolve, filling the interstices between the fibers and resulting in extensive hydrogen bonding. Thorough washing in water, followed by drying on conventional papermaking dryers, causes reprecipitation and consolidation of the network, resulting in a paper that is stronger wet than dry (it has excellent wet strength, even in boiling water), free of lint, odor and taste, and resistant to grease and oils. Unless specially coated or of a heavy weight, it is not a good barrier to gases.
Because of its grease resistance and wet strength, it strips away easily from food material without defibering, thus finding use as an interleaver between slices of food such as meat or pastry. Labels and inserts in products with high oil or grease content are frequently made from parchment. It can be treated with mold inhibitors and used to wrap foods such as cheese.

### 2.7.6 Waxed Paper

Waxed papers provide a barrier against penetration of liquids and vapors. A great many base papers are suitable for waxing, including greaseproof and glassine papers.

Wet-waxed papers have a continuous surface film on one or both sides, achieved by shock-chilling the waxed web immediately after application of the wax. This also imparts a high degree of gloss on the coated surface. Dry-waxed papers are produced using heated rollers and do not have a continuous film on the surfaces. Consequently, exposed fibers act as wicks and transport moisture into the paper. Wax-laminated papers are bonded with a continuous film of wax which acts as an adhesive. The primary purpose of the wax is to provide a moisture barrier and a heat sealable layer. Often special resins or plastic polymers are added to the wax to improve adhesion and low temperature performance, and to prevent cracking as a result of folding and bending of the paper. Replacement of wax coatings by thermoplastics is a continuing trend.

### 2.8 Paperboard Products

#### 2.8.1 Board Types

Paper is generally termed board when its grammage exceeds 224 gsm. Various types of paperboards are manufactured, the major ones being:

- **Linerboard** - board having at least two plies, the top layer being of relatively better quality.

- **Foodboard** - board used for food packaging having a single-ply or multiply construction, usually made from 100% bleached virgin pulp.

- **Folding Boxboard** (Carton Board) - multiply board used to make folding boxes; top ply (liner) is made from virgin pulp,
and the other piles are made from secondary fiber.

d. **Chip Board** - multiply board made from 100% low-grade secondary fiber.

e. **Base Board** - board that will ultimately be coated or covered.

2.8.2 **Folding Cartons**

Folding cartons are containers made from sheets of paperboard (typically with thicknesses between 300 µm and 1100 µm) which have been cut and scored for bending into desired shapes; they are delivered in a collapsed state for erection at the packaging point.

Multiply boards are produced by the consolidation of one or more web plies into a single sheet of paperboard which is then subsequently used to manufacture rigid boxes, folding cartons, beverage cartons and similar products. One advantage of multiply forming is the ability to utilize inexpensive and bulky low grade waste materials (mostly old newspapers and other post-consumer waste papers) in the inner plies of the board where low fiber strength and the presence of extraneous materials (e.g. inks, coatings, etc.) have little effect on board properties. However, multiply boards containing post-consumer waste papers are not used for food contact purposes as any contaminants could migrate into the food.

The boards used for cartons have a ply structure and many different structures are possible, ranging from recycled fibers from a variety of sources, through fibers where the outer ply is replaced with better quality pulps to give white-lined chipboards, to duplex boards without any waste pulp and solid white boards made entirely from bleached chemical pulp.

A number of steps are involved in converting paperboard into cartons. Where special barrier properties are required, coating and laminating is carried out; wax lamination provides a moisture barrier, lining with glassine provides grease resistance, and laminating or extrusion coating with plastic materials such as low density polyethylene confers special...
properties including heat sealing. The use of barrier materials in cartonboard is restricted by the inability of the normal types of carton closure to prevent the ingress of moisture directly.

Coating of the outer board greatly enhances the external appearance and printing quality, and clay and other minerals are used for such purposes. The coating can be applied either during the board-making operation or subsequently. Foil-lined boards are also used for various types of cartons, to (in certain applications) improve reheatability of the contents.

The conventional methods of carton manufacture involve printing of the board, followed by creasing and cutting to permit the subsequent folding to shape, the stripping of any waste material which is not required in the final construction, and the finishing operation of joining appropriate parts of the board, either by gluing, heat sealing or (occasionally) stitching. During creasing and folding, cartonboard is subjected to complex stresses, and the ability of a board to make a good carton depends on its rigidity, ease of ply delamination, and the stretch properties of the printed liner. It is important that the surface layer on the top of the board is of an elastic nature and relatively high strength compared with the properties of the underlying layers since they will be in compression.

2.8.3 Beverage Cartons

The carton normally consists of layers of bleached and (outside North America and Japan) unbleached paperboard coated internally and externally with LDPE, resulting in a carton which is impermeable to liquids and in which the internal and external surfaces may be heat sealed.

The modern gabletop carton retains the simple basic geometry of earlier years although flat-topped and plastic-topped versions are available. Added refinements such as plastic screw caps and reclosable spouts are also available. Incorporation of an aluminum foil layer permits longer shelf life of chilled premium juice products.
Gabletop paperboard cartons with plastic closures

For aseptically-filled cartons a thin layer of aluminum foil which acts as a gas and light barrier is added. The structure and functions of the various layers in an aseptic paperboard carton are described below:

The 6 layers in an aseptic carton from outside to in are:

1. Polyethylene - protects against outside moisture
2. Paper - for stability and strength
3. Polyethylene - adhesion layer
4. Aluminium foil - oxygen, flavour and light barrier
5. Polyethylene - adhesion layer
6. Polyethylene - seals in the liquid

Liquid-tight, hermetically-sealed brick-shaped cartons are widely used for the aseptic packaging of a wide range of liquid foods including milk, juices, soups and wines to give packs which will retain the product in a commercially sterile state for 6-9 months.

Recently a blank-fed, retortable, square-shaped paperboard carton for soups, ready meals, vegetables and pet food has been released commercially. Of basically similar structure to the aseptic carton but with polypropylene replacing low density polyethylene, products packaged in it have a shelf life under ambient conditions of 18 months.

Retortable paperboard cartons

2.8.4 Molded Pulp Containers

The term ‘molded pulp’ is used to describe three dimensional packaging
Paper-based Packaging

2.8.5 Corrugated Cartons

Architects have known for thousands of years that an arch with the proper curve is the strongest way to span a given space. The inventors of corrugated fiberboard applied this same principle to paper when they put arches in the corrugated medium. These arches are known as flutes and when anchored to the liner board with a starch-based adhesive, they resist bending and pressure from all directions. Corrugated fiberboard is a paper-based construction material consisting of a fluted corrugated sheet and one or two flat linerboards. It is widely used in the manufacture of corrugated boxes and shipping containers.

The corrugated medium and linerboard are made of paperboard usually over 0.25 mm thick. Paperboard and corrugated fiberboard are sometimes called cardboard by non-specialists, although cardboard might be any heavy paper-pulp based board.

Corrugated board is characterized by its cellular structure which imparts high compressive strength at relatively low weight. It is constructed of two basic components combined in various ways to produce end products having various characteristics. The two components are the liner and the medium. The liner (or linerboard as it is usually called) is the outside planar sheet which adheres to the flute tips, and the medium is the fluted or corrugated center portion of the board. The heavier-weight liners consist of a number of plies formed on a paper machine, the most commonly used linerboard being 205

and food service articles that are manufactured from an aqueous slurry of cellulosic fibers which is formed into discrete products on screened molds. Typically the raw materials consist of virgin mechanical and chemical wood pulp, and waste paper pulps with or without the addition of the former materials.
gsm unbleached kraft.

Corrugating medium is also expressed in grams per square meter, the usual weight being 127 gsm, with 161 and 185 gsm stock being used for heavier-duty applications. Corrugated box stacking (compressive) strength is more sensitive to medium weight than to liner weight, and hence the use of heavier weights for special applications.

The liner and the medium may be combined in various ways to produce a range of corrugated fiberboards. The simplest is referred to as single-face board and consists of one liner and one medium. Single wall board is the standard board used in corrugated boxes. The addition of further single-face combinations to single-wall board results in double-wall (5 layer) and triple-wall (7 layer) constructions, and such board finds application as corrugated boxes for packaging large, heavy objects or where considerable stacking strength is required.

In addition to the various weights of linerboard and corrugating medium used and the different form of construction of corrugated board, there are five different flute sizes, each varying primarily in the height of the flute and the number of flutes used per unit length of the board. Common flute sizes are A, B, C, E and F or microflute. The letter designation relates to the order that the flutes were invented, not the relative sizes. Flute size refers to the number of flutes per lineal meter or foot. Board thickness is an unreliable metric, due to various manufacturing conditions. The most common flute size in corrugated boxes is C flute. Their dimensions are shown below:

### Standard Flute Sizes in Corrugated Board

<table>
<thead>
<tr>
<th>Type of Flute</th>
<th>Height of Flutes (mm)</th>
<th>Number of Flutes per Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.70</td>
<td>110</td>
</tr>
<tr>
<td>B</td>
<td>2.46</td>
<td>154</td>
</tr>
<tr>
<td>C</td>
<td>3.61</td>
<td>128</td>
</tr>
<tr>
<td>E</td>
<td>1.14</td>
<td>278</td>
</tr>
<tr>
<td>F</td>
<td>0.75</td>
<td>420</td>
</tr>
<tr>
<td>G</td>
<td>0.58</td>
<td>503</td>
</tr>
<tr>
<td>N</td>
<td>0.45</td>
<td>558</td>
</tr>
</tbody>
</table>

A flute is used where maximum cushioning and good top-to-bottom compression is needed. B flute is used when a smooth printing surface is required in addition to high resistance to flat crush. C flute is a compromise between these properties and is the most commonly used sized. The E flute is used to produce board to compete with solid paperboard where its ability to cushion and insulate at very light weights is an advantage, and is widely used in display cases and similar applications, usually combined with high-quality printed liners. G and N...
flutes have been developed to reduce the material content in a package. The lower flute heights of G and N flutes are designed to be directly printed with minimum board crush.

Corrugated board is manufactured on large high-precision machinery lines called corrugators running at 150 lineal meters per minute or faster. In the classical corrugator the paper is humidified by means of high pressure steam with the aim of softening the paper fibers so that the formation of the flute and the consequent gluing will go smoothly. The process adds a considerable amount of water to the paper which has to be removed after formation of the board by drying in the so-called dry-end. Here the newly-formed corrugated board is heated between two hot (120-180°C) plates (top and bottom).

Main flutes for corrugated fiberboard

The choice of corrugated medium, flute size, combining adhesive and linerboards can be varied to engineer a corrugated board with specific properties to match a wide variety of potential uses. Double and triple-wall corrugated board is also produced for high stacking strength and puncture resistance.

**Box Manufacture**

Boxes can be formed in the same plant as the corrugator. Alternatively, sheets of corrugated board may be sent to a different manufacturing facility for box fabrication. The corrugated board is creased or scored to provide controlled bending of the board. Most often, slots are cut to provide flaps on the box. Scoring and slotting can also be accomplished by die-cutting.

Although there are a wide variety of styles of corrugated fiberboard containers, the most common box style is the regular slotted container (RSC), due mainly to its simple construction and economical board usage in terms of board area to volume ratio of the fabricated container. All flaps are the same length and the major flaps meet in the center of the box. However, its poor stacking strength is its major disadvantage, i.e. it rates poorly in terms of volume over strength of fabricated containers. Therefore, when the product can be relied upon to carry most of the static and dynamic stacking load forces (as is the case for canned foods for example), or when internal partitions can carry a significant proportion, the economy of the RSC is unbeatable. However, when the container has to provide protection in addition to simple containment, other less economical container styles must be resorted to.

The dimensions of a corrugated box are always measured from the inside of the box and are expressed as length x width x height. The length is always the first dimension to be expressed and should always be the highest number of the three.
The manufacturer’s joint is most often joined with adhesive but may also be taped or stitched. The box is shipped flat (knocked down) to the packager who sets up the box, fills it, and closes it for shipment. Box closure may be by tape, adhesive, staples, strapping, etc.

### 2.8.6 Solid Fiberboard

Solid fiberboard consists of numerous bonded plies (typically two to five, with three- and four-ply being the most common) of container board lined on one or both faces with kraft or similar paper between 0.13 and 0.30 mm thick to form a solid board of high strength. The total caliper of the lined board ranges from 0.80 to 2.8 mm. Being solid, it is consequently much heavier in weight for a given thickness than corrugated board, the combined weight of the component plies ranging from 556-1758 gsm.

Solid fiberboard containers are generally two to three times the cost of comparable corrugated containers and are therefore used almost exclusively for applications in which container return and reuse are possible. Solid fiberboard containers can be re-used satisfactorily from 10 to 15 times.

Solid fiberboard can be made by passing two or more webs or plies of paperboard between a number of sets of press rolls, adhesive being applied to each ply before it passes through the press nips. In multiple structures it is usual to use a poor grade of paperboard (e.g. chip board) in the central plies and a strong linerboard as the outside facing or liners. After formation of the solid fiberboard, the subsequent operations are similar to those described for corrugated boxes. Many variations of style, quality and properties are possible in both materials.