

# Post Harvest operations and Processing of Fruits, Vegetables, Spices and Plantation Crop Products

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## Lecture 20

### Packaging Methods and Equipment

This lecture covers topics on packaging methods and equipment such as packaging materials, methods and equipment used for fresh produce

#### Concepts Covered

- Packaging materials for fresh produce
- Methods and equipment



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#### Packaging Materials

##### Packaging materials



**Wood**  
Pallets to Crates

**Plastic**  
Containers  
Films/multi-layer/co-extruded  
Flexible films

**Paper**  
Paper bags  
Corrugated boxes



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Different types of materials that are used for packaging of fresh produce includes wood in the form of pallets or crates; plastic in the form of containers, films, multi-layered, co-extruded, and flexible films; paper in the form of bags and corrugated boxes.

## Wood Crates

### Wood crates

- A wooden crate consists of rigid corners with planks nailed or stretched against those corners. Plank thickness varies normally between 3 and 8 mm.
- Cutting the wood will result in loss due to the saw thickness (2-3 mm).
- A slicing machine can be used for thin planks up to 6 mm but these machines are expensive.
- There are several different constructions possible for wooden crates.



Nail crates



Stitch crates



Wire-bound crates



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source: [www.fao.org](http://www.fao.org)

A wood crates consists of rigid corners with planks nailed or stretched against those corners. Plank thickness varies normally between 3 and 8 mm. Cutting the wood will result in loss due to the saw thickness around 2 to 3 mm. A slicing machine can be used for thin planks up to 6 mm but these machines are expensive. Thus, in general hand saw is used for cutting wood to manufacture crates or planks. Different constructions are possible for wooden crates. Which includes nail crates, stitch crates and write-bound crates. The wooden planks and crates are normally used for secondary packaging of the material for shipment or for transportation.

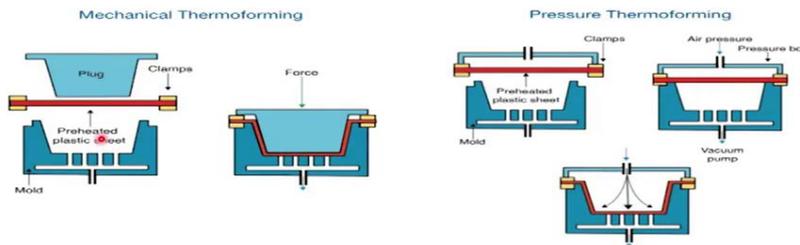
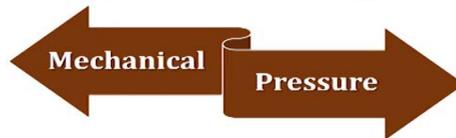
## Plastic Containers

Thermoforming is a process for converting an extruded plastic sheet into small items such as thin wall packaging containers, cups, plates and trays. The two types of thermoforming techniques are mechanical and pressure thermoforming. In mechanical thermoforming preheated plastic sheets, which are marked by red color in the given figure, are formed into a mold in the desired shape of the container by external mechanical force. In pressure thermoforming, air pressure is applied instead of the mechanical force to form the desired shape.

## Plastic containers

- Thermoforming is a process for converting an extruded plastic sheet into small items such as thin wall packaging containers, cups, plates and trays.

### Types of thermoforming

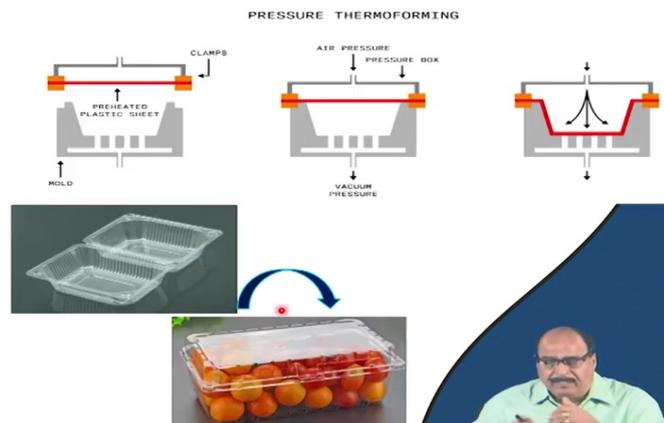


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## Steps of Pressure Thermoforming

### Steps of pressure thermoforming

- Roll or thin plastic sheeting
- ↓
- Pull the material into the machine by vacuum pressure
- ↓
- Heat the sheet few degrees above its  $T_g$  or  $T_m$
- ↓
- Stretch it against a rigid mold
- ↓
- Cool the formed part
- ↓
- Trim the formed part from the non-part



Source: XANTHOS (2000)



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The steps of pressure thermoforming are a roll or thin plastic sheeting followed by pulling the material into the machine by vacuum pressure. The sheet is heated few degrees above its  $T_g$  or  $T_m$  and then it is stretched against a rigid mold by applying the air pressure. In final step, the formed part is cooled and trimmed from the non-part. The pressure thermoformed containers are shown in the picture.

## Multi Layered Films – Blown Film Extrusion

Multi layered films like blown film extrusion is one of the important techniques for making the plastic films. Blown film extrusion is extensively utilized to fabricate multilayered packaging films to improve mechanical, transport, and thermal properties.

## Multi-layered films - Blown film extrusion



Blown film tower

□ **Blown film extrusion** is extensively utilized to fabricate multilayered packaging films to improve mechanical, transport, and thermal properties.

- ✓ Uses compressed air and a set of nip rolls to stretch the film.
- ✓ Utilizes the least amount of floor space, but it needs a lot of height.
- ✓ High output blown film towers are several stories high.



source: Meckley (2017)



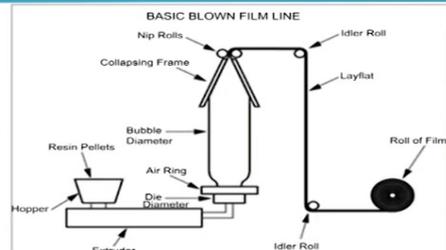
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It uses compressed air and a set up nip rolls to stretch the films. It utilizes the least amount of floor space but it needs a lot of height. High output blown films towers are even several stories high. The picture of a blown film tower that goes on to multi story building is shown in the figure.

### Steps of Blown Film Extrusion

#### Steps of blown film extrusion

- The polymer extrudate exits from the extruder head into the die.
- The die converts a solid flow of molten polymer to a hollow tube of molten polymer.
- The outlet of the tubular die is at 90° to the direction of the extruder.
- The molten polymer flows around the mandrel and emerges through a round opening (also called a ring) to form a tube referred to as the bubble, up in a vertical direction.
- Air is then blown in through the die head into the ring, thereby inflating the tube into a thin tubular bubble.
- This tube is then flattened at the nip rolls and then taken to the winder.



source: Greene (2021); Ashter (2016)



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The steps of the blown film extrusion process are shown in the picture where the first step is the polymer extrudate exiting from the extruder head into a die. The resin pellets are fed into the extruder via the hopper and the polymer enters the die. The die converts the solid flow of molten polymer to a hollow tube and enters the nip roller where it is converted to film rolls. The outlet of the tubular die is at 90 degrees to the direction of the extruder as shown in the figure provided. Thus, the steps involved are, the polymer extrudate exits from the extruder

head into the die. The die converts a solid flow of molten polymer to a hollow tube of molten polymer. The outlet of the tubular die is at 90° to the direction of the extruder. The molten polymer flows around the mandrel and emerges through a round opening (also called a ring) to form a tube referred to as the bubble, up in a vertical direction. Air is then blown in through the die head into the ring, thereby inflating the tube into a thin tubular bubble. This tube is then flattened at the nip rolls and then taken to the winder.

### Blown film extrusion

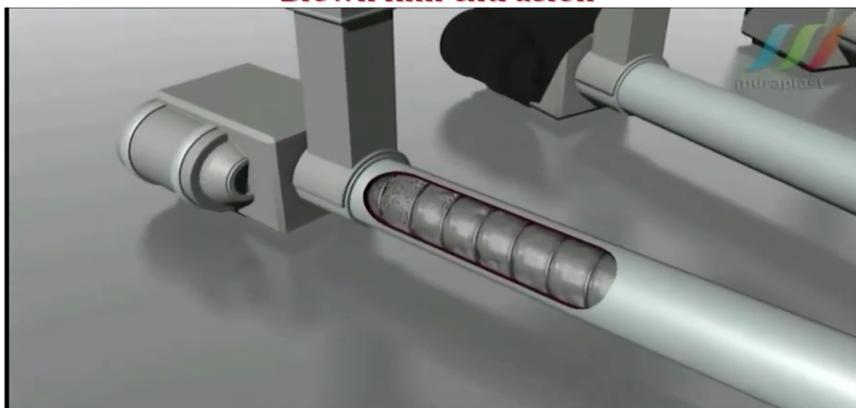


Source :<https://www.youtube.com/watch?v=SzdUoAi9SXk>



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### Blown film extrusion



Source :<https://www.youtube.com/watch?v=SzdUoAi9SXk>



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### Blown film extrusion

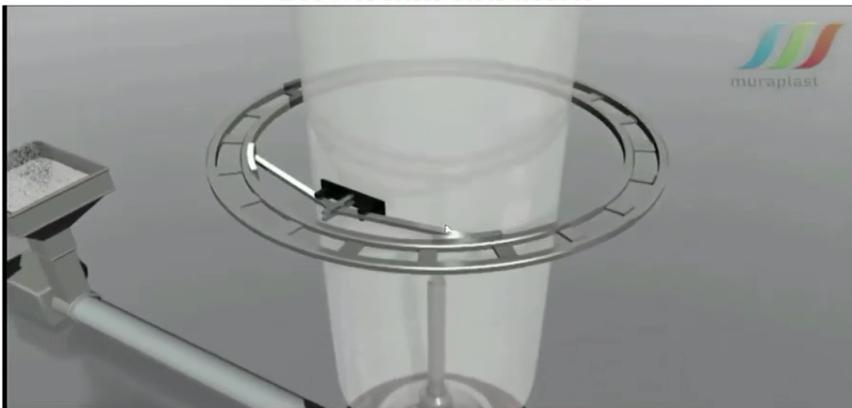


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### Blown film extrusion



Source :<https://www.youtube.com/watch?v=SzdUoAi9SXk>



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### Blown film extrusion

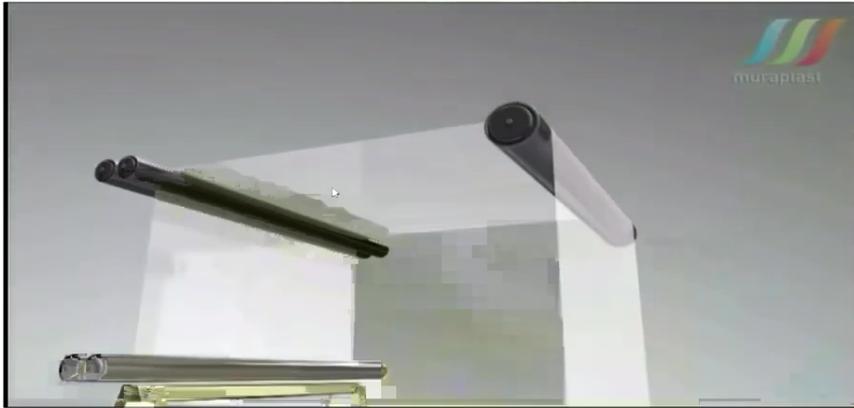


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## Blown film extrusion

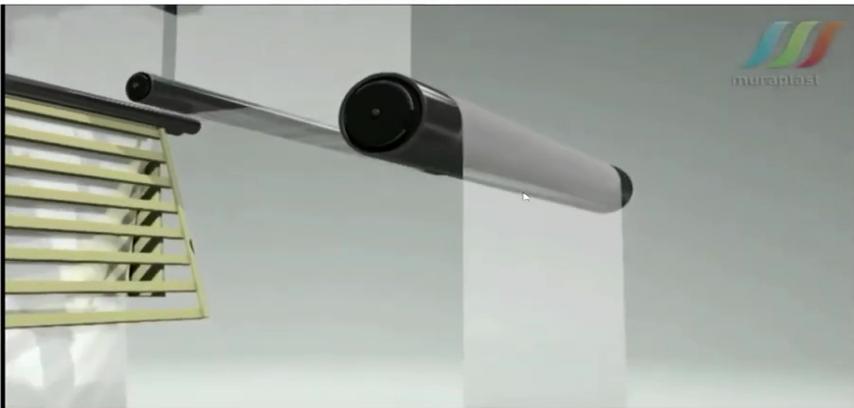


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## Blown film extrusion



Source :<https://www.youtube.com/watch?v=SzdUoAi9SXk>



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## Blown film extrusion



Source :<https://www.youtube.com/watch?v=SzdUoAi9SXk>



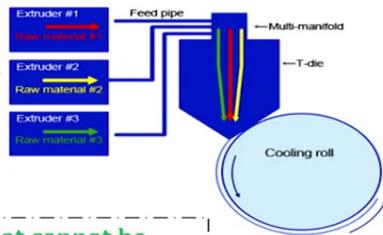
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The molten polymer flows around the mandrel and emerge through a round openings also called a ring to form a tube referred to as the bubble, up in the vertical direction. Air is blown in through the die head into the ring thereby inflating the tube into a thin tubular bubble. This tube is then flattened at the nip roll and taken to the winder. The video provided shows the blown film extrusion process.

## Co-extruded Cast Films

### Co-extruded cast films

❑ Coextruded multi-layer film is produced by a compound molding technique that simultaneously extrudes thermoplastic resin with multiple extruders and passes that through a single die to build up layers of melted resin both on the inside and outside of a film.



Printing surface

Raw material #2
Raw material #1
Raw material #3

Seal surface

*Three-type three-layer film*

Corona treatment

- Extremely thin layers of resin that cannot be made into a film, thus layered by co-extrusion.
- This composite film has properties such as
  - ✓ heat resistance
  - ✓ heat sealing capabilities
  - ✓ rigidity, flexibility
  - ✓ cold resistance
  - ✓ easy-peel capabilities

Source: <https://www.dic-global.com>

Coextruded multilayer film is produced by a compound molding technique that simultaneously extrudes thermoplastic resin with multiple extruders and passes that through a single die to build up layers of melted resin both on the inside and outside of a film. The figure shows different layers of the coextruded cast films such as the three layers of raw materials with printing surface on one side and sealing surface on another side. The different layers of raw materials are passed to three separate setup extruders and the multi manifold is passed through T-die and passed over a cooling roll to form film. So, the extremely thin layers of resin that cannot be made into a film they are layered by co-extrusion. And this composite film has properties such as heat resistance, heat selling capabilities, rigidity, flexibility, cold resistance, or easy-peel capability etc. Such films are used in aseptic processing and packaging of dairy products, fruits, juices, and vegetable juices.

## Flexible Films

Flexible polymer films are produced by cast extrusion and blown film extrusion. A multi-layer film can be obtained by the co-extrusion of different polymeric materials by adhesive lamination of several plastic films or by extrusion lamination.

## Flexible films

Polymer films are produced by **cast extrusion** and **blown film extrusion**.

A multilayer film can be obtained by the **co-extrusion of different polymeric materials**, by **adhesive lamination of several plastic films**, or by **extrusion lamination**.

- A **tenter frame** can be used to **orient bi-axially cast films**.

Improvement of barrier properties of plastic films by **lacquering the surface** or depositing a very thin layer of **aluminum (metallization)** or of **silicon or aluminum oxide**.

- ❑ **Typical adhesives used in laminating processes are waterborne, solvent based, hot melt, or reactive 100% solids (solvent less).**

source: Buonocore et al. (2014)



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A tender frame can be used to orient biaxially cast films. Improvement of the barrier properties of plastic films is possible by lacquering the surface or depositing a very thin layer of aluminum (metallization) or of silicon or aluminum oxide. Lacquering a thin layer of aluminum or of silicon or aluminum oxide improves the printability of the films. The films could also have a paper layer for added advantage. Typical adhesives used in laminating processes are waterborne, solvent based, hot melt or reactive 100 % solids that are solvent less.

## Examples of Flexible Packaging

### Examples of flexible packaging



Flexible laminated rolls



Stand-up pouch



Centre seal pouch



Side seal pouch



Gusset pouch



Fresh fruit packaging

source: <https://www.dupack.in/flexible-packaging-films/>; <https://www.indiamart.com/proddetail/fruits-packaging-pvc-cling-film-10086456897.html>



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Few examples of flexible packaging such as laminated rolls, stand up pouch, centre seal pouch, side seal pouch and gusset pouch are shown in the slide. Fresh fruits and vegetables can be packed in the laminated film pouches as shown in the figure.

### Vegetables Packaging Machine

**Vegetables packaging machine**



source: [https://www.youtube.com/watch?v=Tz5Da\\_AX3E](https://www.youtube.com/watch?v=Tz5Da_AX3E)

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**Vegetables packaging machine**



source: [https://www.youtube.com/watch?v=Tz5Da\\_AX3E](https://www.youtube.com/watch?v=Tz5Da_AX3E)

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### Vegetables packaging machine



source: [https://www.youtube.com/watch?v=Iz5Da\\_AX3E/](https://www.youtube.com/watch?v=Iz5Da_AX3E/)



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### Vegetables packaging machine



source: [https://www.youtube.com/watch?v=Iz5Da\\_AX3E/](https://www.youtube.com/watch?v=Iz5Da_AX3E/)



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### Vegetables packaging machine



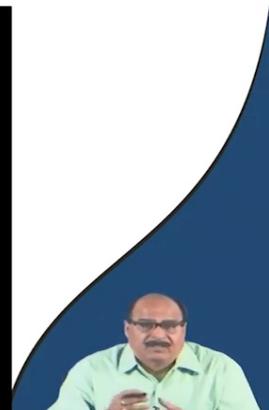
source: [https://www.youtube.com/watch?v=Iz5Da\\_AX3E/](https://www.youtube.com/watch?v=Iz5Da_AX3E/)



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## Vegetables packaging machine



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The video shows vegetables being washed and packaged in plastic films. It measures the length of the vegetables to be packed and decides the dimension of the film required for packaging automatically.

## Vegetables in Flexible Packages

### Vegetables in flexible packages



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## Vegetables in flexible packages

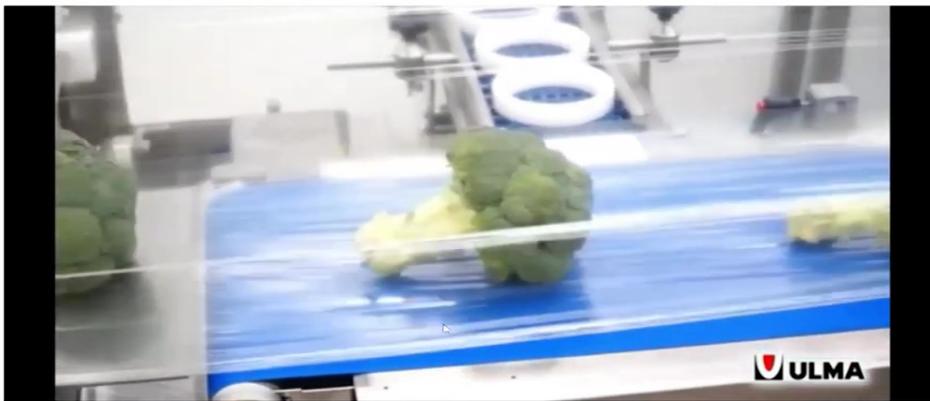


source: <https://youtu.be/ZiHC1TLf5jg>



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## Vegetables in flexible packages



source: <https://youtu.be/ZiHC1TLf5jg>



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## Vegetables in flexible packages



source: <https://youtu.be/ZiHC1TLf5jg>



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## Vegetables in flexible packages



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## Vegetables in flexible packages



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The video shows packaging of vegetable in flexible package. The broccoli is cleaned and wrapped in plastic pouches, which is compressed and sealed in a vacuum chamber.

### Overwrap Packaging with or without Tray

The video shows packaging of vegetables with tray. The vegetables are placed on a tray and wrapped with a plastic film and passed through the vacuum chamber.

## Overwrap packaging with or without trays



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## Overwrap packaging with or without trays



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## Overwrap packaging with or without trays



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## Overwrap packaging with or without trays



source: www.sseengrindia.in



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## Overwrap packaging with or without trays



source: www.sseengrindia.in



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## Overwrap packaging with or without trays



source: www.sseengrindia.in



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## Overwrap packaging with or without trays



source: www.sengrindia.in



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source: www.sengrindia.in



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## Overwrap packaging with or without trays



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## Overwrap packaging with or without trays



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## Overwrap packaging with or without trays



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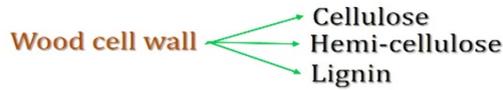
The other video shows individual vegetable like carrot, egg plants and cucumbers being packed without a tray.

## Paper

Paper is another one of the most commonly used packaging material. The raw material of the paper severely affects the quality due to its variation in fiber length and pulp composition. Paper can be manufactured from cottonseed, hair, flax leaves, sunflower stalk and even agricultural waste.

## Paper

- Raw material of the paper severely affects the quality due to its variation in fibre length and pulp composition.
- Paper can be manufactured from cottonseed hair, flax leaves, sunflower stalk and agricultural waste.



Cellulose Fibre-forming properties.

Hemicellulose Responsible for the hydration of pulp and development of bonding during beating process.

Lignin Natural binding constituent of wood cells with no fibre forming ability.

source: Deshwal et al. (2019)

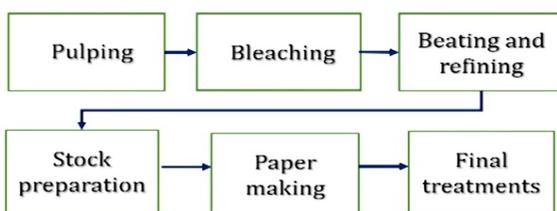


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Wood cell wall consists of cellulose, hemi-cellulose and lignin, which provide certain property that are useful in converting them to paper. Cellulose has fibre forming properties, while hemicellulose is responsible for the hydration of pulp and the development of bonding during beating processes. Lignin is a natural binding constituent of wood cells with no fiber forming ability.

## Steps of Paper Preparation Process

### Steps of paper preparation process



- Pulping is the process of separating wood fibers using mechanical, chemical, or thermal treatments or in combination.
- Lignin is dissolved to produce individual fibers during pulping which can be reformed to paper sheet during paper making process.
- The solution or the fibers obtained after the pulping treatment is known as pulp.

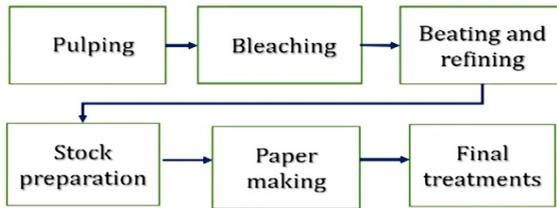
source: Deshwal et al. (2019)



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Different steps in the paper preparation process are pulping, bleaching, beating and refining followed by stock preparation, paper making and final treatments. Pulping is the process of separating wood fibers using mechanical, chemical or thermal treatments or in combination. Lignin is dissolved to produce individual fibers during pulping which can be reformed to paper sheet during paper making process. The solution or the fibers obtained after the pulping treatment is known as the pulp.

## Steps of paper preparation process



- Bleaching treatment is applied to improve the whiteness of chemical and mechanical pulp.
- Chromophoric groups of lignin are responsible for color of the pulp which are removed during bleaching by using chlorine, chlorine dioxide or hydrogen peroxide.

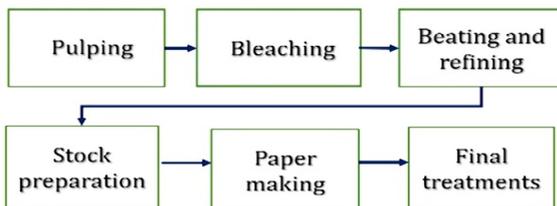
source: Deshwal et al. (2019)



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Next step is the bleaching process in which bleaching treatment is applied to improve the whiteness of the chemical and mechanical pulp. Chromatography groups of lignin are responsible for color of the pulp which are removed during bleaching by using chlorine, chlorine dioxide or hydrogen peroxide.

## Steps of paper preparation process



- Beating treatment increase the surface area of the fibers thus increasing their water holding capacity and creating additional bonding opportunities for fibers.
- Refining process is similar to beating process.
- Improves the physical properties of the finished sheet.
- Stock preparation stage involves the mechanical treatment of pulp for its conversion into a sheet on paper machine.

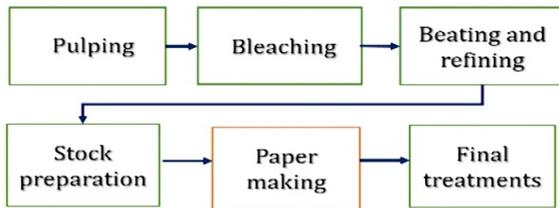
source: Deshwal et al. (2019)



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The bleached pulp is then subjected to a process called beating and refining. Beating treatment increases the surface area of the fibers, thus increasing their water holding capacity and creating additional bonding opportunities for fibers. Refining process is similar to beating process, it improves the physical properties of the finished sheet. The stock preparation stage involves the mechanical treatment of pulp for its conversion into a sheet on paper machine.

### Steps of paper preparation process



- Paper making process involves mainly 3 different methods: Fourdrinier machine, cylinder machine and twin wire formers.
- The fibrous material (approx. 99% water) is passed through rollers or wire mesh to remove water and form the paper web.

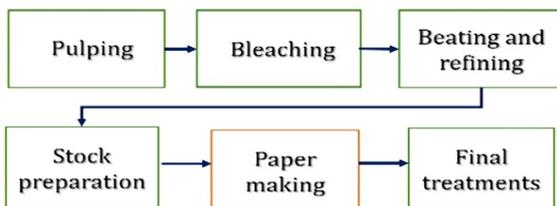
source: Deshwal et al. (2019)



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Final process is the paper making which process involves mainly three different methods, fourdrinier machine, cylinder machine and twin wire formers. The fibrous material with approximately 99% water is passed through the rollers or wire mesh to remove water and form the paper web.

### Steps of paper preparation process



- Final treatments include calendaring, supercalendering, sizing, laminating, impregnating or saturating the developed paper as per the requirement of the industry or the product to be packed.

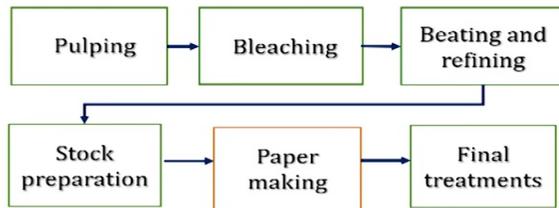
source: Deshwal et al. (2019)



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Then final treatment is given that includes calendaring, supercalendering, sizing, laminating, impregnating or saturating the developed paper as per the requirement of the industry or the product to be packaged.

## Steps of paper preparation process



### Based on the grade

Virgin paper or virgin grade paper  
Recycled paper

### Based on the smoothness and treatment

Bleached pulp → Fine paper  
Unbleached pulp → Coarse paper

source: Deshwal et al. (2019)



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Based on the grade that papers are classified as virgin paper or virgin grade paper or recycled paper. Based on the smoothness and treatment, it can be classified as bleached pulp, which is considered as a fine paper or unbleached pulp that is coarse paper.

## Paper Bags

### Paper bags

- Different types of paper like grease resistant, kraft paper, recycled kraft, coated papers, wax impregnated, laminated papers are used in its manufacturing.
- Available in different forms such as flat and satchel, self-opening satchel (SOS) bags, strip window bags, etc.
- Research studies had been conducted for the use of lignocellulosic micro/nano fibres from sawdust with recycled cardboard.



#### Pros

- Biodegradable, reusable, recyclable.
- Many paper bags can withstand more pressure or weight than plastic bags.
- Less suffocation risk to young children or animals.

#### Cons

- Aren't water proof.
- More expensive than plastic bags.
- Require more storage space and are relatively heavier than plastic.

#### Basic information on paper bag types and capacities

Bag Type	Capacity	Length	Width	Height
Lunch Bags	1/2 - 5 lb.	11"	3 - 5 1/4"	5 - 10"
Grocery Bags	2 - 25 lb.	17"	4 - 12"	7 - 18"
Beer, Liquor, and Wine Bags	Varies	Varies	3 - 10"	11 - 16"
Baguette Bread Bags	Varies	--	4 - 5 1/2"	16 - 28"
Produce Bags	1/4 - 1 pk.	Varies	6 - 8"	8 - 10 1/2"
Recloseable Tin Tie Coffee Bags	1/2 - 8 lb.	9 3/4"	4 - 6 1/2"	7 - 16"
Merchandise Bags	Varies	--	6 - 21"	9 - 24"

source: <https://www.webstaurantstore.com/>



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Different types of paper like grease resistant, kraft paper, recycled kraft, coated papers, wax impregnated, laminated papers are used for manufacturing of paper bags. They are available in different forms such as flat and satchel, self-opening satchel (SOS) bags, strip window bags, et cetra. Research studies had been conducted for the use of lignocellulosic micro or nano fibers from the sawdust with recycled cardboard. The pros include they are biodegradable, reusable, recyclable. Many paper bags can withstand more pressure or weight

than plastic bags. Less suffocation risk to young children or animals. The disadvantages are that they are not waterproof, more expensive than plastic bags, require more storage space and are relatively heavier than plastic. The table provided shows basic information on paper bag types and their capacities. Different types of paper bags available in the market are lunch bags, grocery bags, beer liquor and wine bags, baguette bread bags, produce bags, recloseable tin tie coffee bags or merchandise bags. The capacity of the bags varies from half to 8 pounds. Their length, width and height information are also provided in the table given.

## Corrugated Fiberboard (CFD)

### Corrugated fibreboard (CFB)

- The raw material for CFB is mainly kraft paper, however, agave bagasse, by-products from the tequila industry had also been used.
- It consists of two or more layers of flat kraft paper (liner) and layers of corrugated material (flute) sandwiched between the flat layers to provide cushioning effect and abrasion resistance.
- Fluted material is developed using corrugator which involves passage of flat kraft paper between two serrated rollers, followed by application of adhesive to the tips of corrugations and liner is stuck to the corrugated material using pressure.

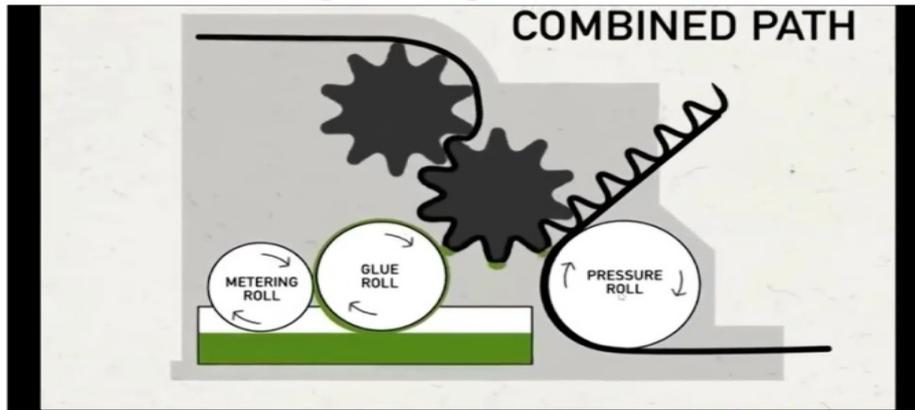


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The raw material for CFB is mainly Kraft paper. However, agave bagasse, by-products from the tequila industry had also been used. It consists of two or more layers of flat kraft paper that is liner and layers of corrugated material called flute, sandwiched between the flat layers to provide cushioning effect and abrasion resistance. The fluted material is developed using corrugator which involves passage of flat kraft paper between two serrated rollers, followed by application of adhesive to the tips of the corrugations and liner is stuck to the corrugated material using pressure. The figure shows the fiber board used for packing of fruits.

## Making of Corrugated Fiber Board

## Making of corrugated fibreboard



source: <http://www.gpcorrugatcd.com>

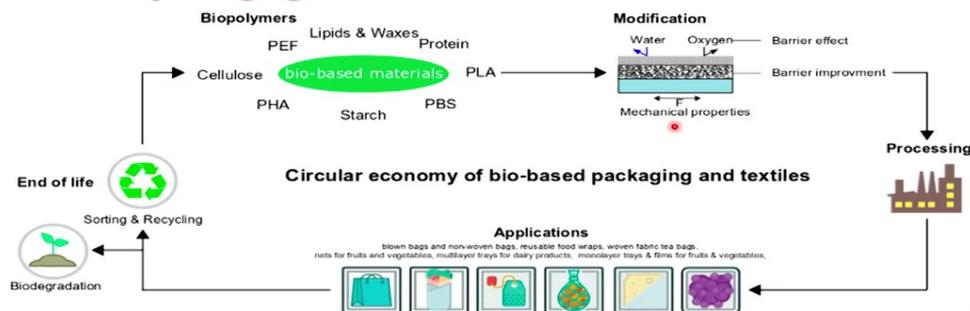


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The making process of corrugated fiber board is shown in the video. The paper material is passed between two rollers, followed by pressure roll, glue roll and finally the metering roll.

## Bio-based Packaging

### Bio-based packaging



#### • Two type of extrusion processing

- ✓ Single-screw extrusion which is applied for general polymer processing (**Blow moulding**, **Cast film extrusion**, and **Injection moulding**).
- ✓ Twin screw used for compounding and polymer blending.



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Bio based packaging is becoming more due to its main advantage of circular economy and reusability. Bio based packaging can be made bio degradable thus reducing the havoc caused by environmental pollution. In this type of packaging, biopolymers like cellulose, PEF, lipids and waxes, proteins, PLA, PBS, starch, and PHA are used. The biopolymers are subjected to further modification processed to improve its barrier properties like water barrier property, and oxygen barrier properties. Through extrusion technology they are converted to laminates. They are used for various packaging applications such as blown bags, non-blown bags, food wraps, woven fabric tea bags, nets for fruits and vegetable, multilayer trays for dairy

products, monolayer trays and films for fruits and vegetables. These packaging are biodegradable and recyclable. Two types of extrusion processing are used for biobased packaging materials such as single-screw extrusion which is applied for general polymer processing, that is blow molding, cast film extrusion and injection molding. The other type is twin screw extrusion process which is used for compounding and polymer blending. Thus,

- ✓ Made from **hybrid carrageenan** (extracted from *Mastocarpus stellatus* seaweeds), and **rice starch**.
- ✓ Thin, flexible, and transparent films with enhanced UV barrier, oxygen barrier, and hydrophobic properties.
- ✓ Promising material for all the applications requiring a moderate gas exchange through the packaging material.

source: Larotonda et al. (2016)

- ✓ **YPACK's packaging** is made from a sustainable biopolymer, poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), created using cheese whey and micro-cellulose from almond shells.
- ✓ It showed a short-term (15 days) and medium-term (up to 48 days) anti-bacterial effects in 'open' and 'closed' systems.

source: <https://www.innovationnetwork.com/news/compostable-bioplastics-to-extend-the-shelf-life-of-food/5190>

either single screw extrusion or twin screws extrusion could be used depending upon the properties that are desired in the material.

The slide shows fruits and vegetables packed in bio-based plastic packaging materials that has been developed. The figure shows fruits packed in biodegradable material made from hybrid carrageenan that is extracted from *Mastocarpus stellatus* seaweeds and rice starch. These are thin, flexible and transparent films with enhanced UV barrier properties, oxygen barrier properties and hydrophobic properties. The packaging material is promising for all the applications requiring a moderate gas exchange through the packaging material. The barrier properties of the packaging materials are tailored according to the type of the produce. It should allow moderate level of oxygen to come in and let out carbon dioxide to maintain the aerobic respiration. The packaging should also provide sufficient strength.

YPACK packaging is made from is made from a sustainable biopolymer, poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), created using cheese whey and micro-cellulose from almond shells. It showed a short-term (15 days) and medium-term (up to 48 days) anti-bacterial effects in 'open' and 'closed' systems.

## Summary

- ✓ Wooden crates are used for transportation of food products to longer distances.
- ✓ **Plastics in the form of trays, containers are produced by blown film extrusion or cast film extrusion.**
- ✓ The films can be co-extruded to incorporate multiple film attributes.
- ✓ **Although, paper do not provide enough mechanical strength, due to its reusability and biodegradability, paper bags are gaining popularity.**
- ✓ Bio-based packaging materials are now in trend due to its sustainability, multiple film properties and good storage life.



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Now, the trend towards packaging of fresh produce is coming towards bio-based packaging material. They can be reused and are biodegradable, thus addressing the environmental problems.

The summary of the lecture are wooden crates are used for transportation of food products to longer distances. Plastics in the form of trays, containers are produced by blown film extrusion or cast film extrusion. The films can be co-extruded to incorporate multiple film attributes. Although, paper do not provide enough mechanical strength, due to its reusability and biodegradability, paper bags are gaining popularity. Bio-based packaging materials are now in trend due to its sustainability, multiple film properties and good storage life.

The reference for further reading are provided in the slides.

## References

- Ashter, S. A. (2016). 7-processing biodegradable polymers. Introduction to Bioplastics Engineering, 179-209.
- Buonocore, G., Sico, G., & Mensitieri, G. (2014). Safety of Food and Beverages: Packaging Material and Auxiliary Items. In Y. Motarjemi (Ed.), Encyclopedia of Food Safety (pp. 384–396). Academic Press.  
<https://doi.org/https://doi.org/10.1016/B978-0-12-378612-8.00297-3>
- Deshwal, G. K., Panjagari, N. R., & Alam, T. (2019). An overview of paper and paper based food packaging materials: Health safety and environmental concerns. Journal of food science and technology, 56(10), 4391-4403.
- GÖKMEN, V., & MORALES, F. (2014). Encyclopedia of Food Safety.
- Greene, J. P. (2021). Automotive Plastics and Composites: Materials and Processing. Elsevier.
- <https://www.dicglobal.com/en/products/film/about.html#:~:text=Coextruded%20multi%2Dlayer%20film%20is,and%20outside%20of%20a%20film.>
- <https://www.webstaurantstore.com/blog/139/should-your-restaurant-or-take-out-business-use-paper-bags.html>
- Iñiguez-Covarrubias, G., Lange, S. E., & Rowell, R. M. (2001). Utilization of byproducts from the tequila industry: part 1: agave bagasse as a raw material for animal feeding and fiberboard production. Bioresource Technology, 77(1), 25-32.



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## References

- Khwaldia, K., Arab-Tehrany, E., & Desobry, S. (2010). Biopolymer coatings on paper packaging materials. *Comprehensive reviews in food science and food safety*, 9(1), 82-91.
- Kirwan, M. J. (2005). 2 Environmental and waste management issues. In *Paper and Paperboard Packaging Technology* (pp. 68-71). Blackwell Publishing Ltd. Oxford, UK.
- Larotonda, F. D., Torres, M. D., Gonçalves, M. P., Sereno, A. M., & Hilliou, L. (2016). Hybrid carrageenan-based formulations for edible film preparation: Benchmarking with kappa carrageenan. *Journal of Applied Polymer Science*, 133(2).
- Meckley, J. (2017). Plastic Film Production. In *A Guide to the Manufacture, Performance, and Potential of Plastics in Agriculture* (pp. 21-43). Elsevier.
- Rudi, H., Resalati, H., Eshkiki, R. B., & Kermanian, H. (2016). Sunflower stalk neutral sulfite semi-chemical pulp: an alternative fiber source for production of fluting paper. *Journal of Cleaner Production*, 127, 562-566.
- Xanthos, M. (2000). Polymer processing. In *Applied Polymer Science: 21st Century* (pp. 355-371). Pergamon.

