Chapter I Packaging of agriculture products

1. post-harvest technology

1.1.Importance of post-harvest technology

Fresh fruits and vegetables have been part of human diet and their nutritional value was recognized. Fruits and vegetables are being rich in vitamins and minerals, known as protective foods. Due their high nutritive valve, ready availability, and being inexpensive they make significantly contributes to human well-being. They are living biological entities, they will deteriorate after harvest. The rate of deterioration varies greatly among products depending on their overall rate of metabolism, but for many it can be rapid. Harvest is a specific and single deliberate action to separates the food stuff with or without non-edible portion from its growth medium. For the examples: the plucking of fruits and legumes. The post-harvest system, which encompasses all the technical and steps that occur immediately after the product is separated from its growing environment (harvest) until its final consumption. The main objective of these techniques is to extend the "post-harvest shelf life" by slowing down natural degradation (senescence) and preserving the nutritional and marketable quality of the product.An example of the importance of the field to post-harvest handling is the discovery that ripening of fruit can be delayed, and thus their storage prolonged, by preventing fruit tissue respiration. Another well-known example is the finding that ripening may be brought on by treatment with ethylene.

1.2. Post- harvest techniques

1.2.1. Initial preparation

1.2.1.1. Cleaning/washing

Cleaning and washing involve the systematic removal of soil, dust, organic debris, and pesticide residues from the surface of the produce. This step is crucial for food safety, as it eliminates surface pathogens (bacteria, fungi, or parasites) that could cause diseases in consumers. It significantly improves the visual appeal and marketability of the product by making it look clean and fresh for the consumer. By removing contaminated soil and spores, washing helps prevent the spread of post-harvest infections between healthy and infected items in a container.

- **Methods for cleaning and washing**

- **Dry cleaning:** Using sieves to remove soil and debris without wetting the product (ideal for onions or potatoes).

- **Wash tanks:** Immersing products in agitated water, often with added disinfectants (such as chlorine) to prevent moisture from encouraging mold growth.
- **Spray washing:** Using high-pressure water jets to dislodge stubborn dirt from uneven surfaces.
- **Sanitizing:** Adding chemical agents (ozone, chlorine dioxide) to the wash water to ensure complete sanitary safety.

1.2.1.2. Pre-cooling

Pre-cooling is the rapid removal of field heat from freshly harvested crops to slow down their metabolism. The field heat refers to the thermal energy accumulated by the plant in the field due to solar radiation and high ambient temperatures. Fruits and vegetables are living organisms that continue to perform respiration after harvest, consuming oxygen and releasing carbon dioxide, water, and heat. The higher the temperature, the faster the respiration rate. If a crop breathes too rapidly, it quickly exhausts its internal sugar and water reserves, leading to wilting, shriveling, and accelerated decay. The primary objective of pre-cooling is to lower the product's temperature from 30°C to its ideal range (2°C to 5°C) in record time. By cooling the product immediately, we put the fruit into a state of "hibernation," drastically slowing its respiration to preserve freshness during transport. In essence, pre-cooling prevents the product from "consuming itself" and significantly extends its post-harvest shelf life.

- **Methods for Pre-cooling**

- **Room cooling**: Placing products in a standard cold room. This is the simplest but slowest method.
- **Forced-air cooling**: Using powerful fans to force cold air through the packaging. This is much faster than simple room cooling.
- **Hydro-cooling**: Immersion or spraying with ice water. This is the fastest method for products that tolerate humidity (such as carrots or sweetcorn).
- **Icing (glazing):** Application of crushed ice directly onto or into product crates (often used for broccoli).

1.2.1.3. Trimming

Trimming refers to the physical removal of unwanted, inedible, or damaged parts of the plant material after harvest. The main objective is to improve the visual appearance of the product

and remove parts that may harbor diseases or pests. It involves cutting away withered leaves (like on lettuce), long roots, stems, or any bruised tissue that could accelerate rot. While it enhances the market value, by removing decaying parts, trimming reduces ethylene production and prevents the spread of infection to healthy produce in the same batch.

- **Methods for trimming**

- **Manual Trimming:** Using knives, shears, or scissors to remove unwanted parts.
- **Mechanical Trimming (Automated)**: Industrial machines equipped with rotating blades or vibrating cutters. Used for high-volume products with uniform shapes, such as topping and tailing carrots, onions, or green beans.

I.2.2. Preservation treatments

I.2.2.1.Curing

Curing is a post-harvest process involving partial drying of the outer layers of certain crops (like onions, garlic, or tubers) to strengthen their natural protection. The main objective is to harden the skin and promote the healing of harvest wounds (a process called suberization in potatoes). By drying the surface and the neck (for onions), it creates a physical barrier that prevents the entry of pathogens (bacteria and fungi) during storage. This treatment significantly reduces water loss and prepares the product for long-term storage or long-distance transport.

- **Curing Methods**

- **Field curing**: The crops are left in the field in windrows for several days to dry under the sun and wind. Highly dependent on weather conditions (rain can ruin the process).
- **Forced-air curing**: Products are placed in sheds where warm, dry air is blown through them using powerful fans. Faster and more controlled than field curing.

I.2.2.2.Waxing

Waxing consists of applying a thin layer of edible wax or protective coating to the surface of fruits and vegetables. The primary goal is to replace the natural waxes lost during washing, creating a barrier that minimizes perspiration (water loss) and prevents shriveling (flétrissement). The wax coating acts as a "modified atmosphere," slightly restricting gas exchange to slow down the respiration rate and extend shelf life. It gives the produce a glossy, bright appearance, making it more attractive to consumers. The coating can also seal

tiny scratches or "micro-wounds" on the skin, reducing the entry points for decay-causing organisms.

- **Waxing Methods**

- **Spraying (pulvérisation)**: The most common industrial method where liquid wax is atomized
- **Brushing (brossage)**: Rotating horsehair or synthetic brushes spread the wax evenly across the entire surface of the product to ensure full coverage.
- **Dipping (trempage)**: The produce is briefly submerged in a wax emulsion tank (effective but uses more wax).
- **Foaming (mousse):** Wax is applied as a foam, which provides excellent coverage while using less water and drying faster than other methods.

I.2.2.3. Chemical treatments

Chemical treatments consist of applying specific substances to prevent biological deterioration or undesirable physiological changes after harvest. The main use is the application of fungicides to eliminate or inhibit the growth of molds and fungi responsible for rot (such as *Penicillium* on citrus fruits). Sprouting inhibitors (such as CIPC) are applied to tubers (potatoes) or bulbs (onions) to prevent sprouting during prolonged storage. Some treatments include antioxidants or anti-browning agents to preserve the product's color. All chemicals used must comply with strict maximum residue limits (MRLs) to ensure their safety for human consumption.

- **Chemical treatments methods**

- **Soaking**: The product is immersed in a tank containing a chemical solution for a specified period.
- **Fumigation (gasification)**: The product is placed in an chamber where the chemical is released as a gas or smoke.
- Treated packaging/pads: The fruit is placed in paper impregnated with chemicals that slowly release protective vapors.

I.2.3. Quality and logistics management

I.2.3.1. Sorting and grading

Sorting and grading consist of categorizing the produce into uniform groups based on physical and quality characteristics. The goal is to ensure the product meets specific commercial standards (Category I, II, or extra), which determines its final price and destination. Sorting is the initial step to remove defective items (damaged, diseased, or misshapen) to prevent them from contaminating the rest of the batch. Grading (classification) is separated the produce into classes based on size and weight: To ensure uniformity in packaging, on quality and color to meet consumer preferences and ripeness requirements.

- **Methods of sorting and grading**
  - **Manual sorting**: Trained workers visually inspect the produce and remove culls by hand.

I.2.3.2. Packaging

Etymologically, the word "packaging" comes from the word "emballer," which literally means "to wrap in a bale." However, packaging is defined as all the materials used to protect the nutritional and organoleptic qualities of plant products throughout the entire supply chain, from distribution to the end consumer. Packaging refers to the technology of enclosing or protecting products for distribution, storage, sale, and use. Its primary role is to act as a buffer, protecting the produce from mechanical injuries like bruising, crushing, or vibration during handling. It helps maintain a microenvironment around the product, reducing moisture loss and protecting it from dust or external contaminants. It standardizes the shape and size of units (crates, boxes), making it much easier to stack, load, and transport large quantities. The package serves as a communication tool, providing essential data such as origin, variety and weight.

- **Packaging Types**
  - **Primary Packaging**

This packaging is in direct contact with the product in order to contain and preserve it. This packaging must be compatible with the product and protect it from any external contaminants that could cause unwanted degradation.

Figure 1. Different types of packaging.

- **Secondary Packaging**

This is often used to protect the unit or to facilitate product use. Several primary packages may be contained within a secondary package, which therefore corresponds to the sales unit.

- **Shipping packaging**

This includes several secondary packaging materials for protecting the containers during transport.

- **Transport Packaging**

This is often done using reusable wooden or plastic pallets which allow for the transport, storage and of certain quantities of shipping units.

- **Packaging Evaluation**

There are several criteria we can use and adopt to evaluate each package, including:

• **Visibility and Attractiveness**: This refers to the ability to capture attention and pique the consumer's interest.

• **Legibility**: Is the label easy to read?

• **Personality**: Does the packaging accurately and completely convey the product's image?

• **Differentiation:** Does the product stand out from competing products?

- **Importance of packaging**

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Packaging can be the key factor in a processing method. Furthermore, it is the first element the consumer encounters and significantly influences their purchasing decision because the packaging often represents the means of communication between the manufacturer and the consumer. Packaging for plant-based products (fruits, vegetables, grains, etc.) is essential to preserve their freshness, prevent physical damage, and extend their shelf life.

- **Requirements of packaging**

In general, food packaging must fulfil the following requirements:

- It must protect the food against a range of hazards during distribution and storage. This includes serving as a barrier to dirt, microorganisms and other contaminants; protecting the food from damage caused by insects, birds and rodents; protecting it from crushing or other physical damage; and protecting it from the effects of heat and light that can cause rancidity, or moisture pickup wilting or other types of quality deterioration.
- It should be suitable for recycling or re-use, or be easily disposed of to prevent waste packaging from causing environmental pollution.

- **Packaging methods**

Packaging types are generally distinguished by their shape, material.

- **Packaging by shape**

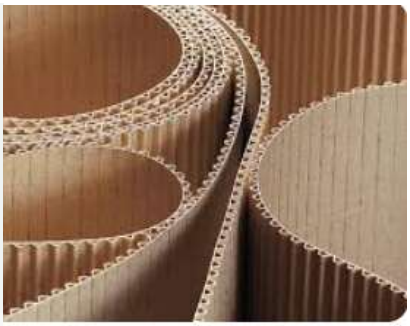
- **Crates/Boxes**: Cartes and boxes made of wood, plastic, or corrugated cardboard, these are used for the bulk transport of robust products such as apples, potatoes, or tomatoes.

- **Trays:** Often made of rigid plastic (PET) or recycled paper pulp, these are ideal for delicate products such as berries or cherry tomatoes.


- **Bags/Mesh Bags**: Polyethylene bags retain moisture for leafy greens, while mesh bags allow maximum ventilation for onions and citrus fruits


- **Packaging materials**

- **Corrugated cardboard**: The dominant material for shipping due to its strength-to-weight ratio. This structure offers good mechanical strength and thermal insulation properties.

- **Plastics**: Polypropylene (PP), polyethylene (PE), and PET are preferred for their lightness and transparency.
- **Bio-based materials**: Increasing use of PLA (polylactic acid) derived from corn ad sugarcane bagasse, or algae utilization to reduce environmental impact. PLA is one of the most well known bio-based polymers. This biopolymer has attracted significant attention in the packaging industry, as it is a biodegradable thermoplastic aliphatic polyester, derived from fermented vegetable starch (corn or sugarcane), being a renewable alternative to plastics. PLA is synthesized starting from fermentation of renewable resources (e.g., corn or sugarcane) to produce lactic acid (LA) followed by polymerization. Various polymerization methods, such as direct polycondensation, enzymatic polymerization of PLA from LA .

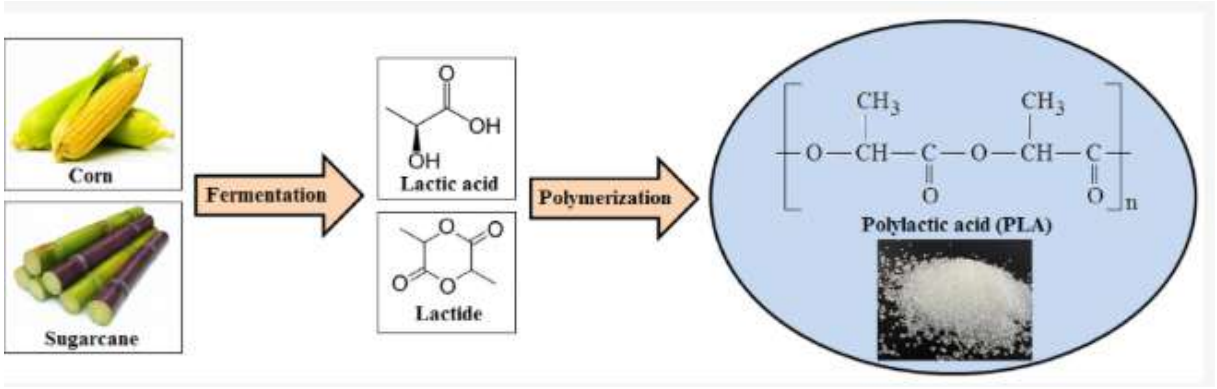


Figure 2. Bio-based materials.

I.2.3.3. Storage and ripening:

Storage is the holding of produce under controlled conditions, while ripening is the process of inducing physiological changes to reach peak eating quality.

- **Temperature control**: is the most critical factor; maintaining the "cold chain" slows down respiration and prevents the growth of spoilage microorganisms.
- **Atmosphere control**: By adjusting levels of oxygen (O_2) and carbon dioxide (CO_2), we can "suffocate" the ripening process to keep fruits firm for several months (Controlled Atmosphere Storage).
- **Humidity management**: High relative humidity (85-95%) is maintained to prevent water loss and wilting. For fruits (like bananas, avocados, or tomatoes), ethylene gas is artificially introduced in specialized rooms to ensure uniform and timely ripening.

➢ **Methods**

- **Cold rooms** Insulated rooms equipped with refrigeration units to maintain a constant, low temperature.
- **Controlled atmosphere storage**: airtight warehouses where gas levels are precisely monitored (controlled) and adjusted by computers to stop the aging of the fruit.
- **Ripening rooms**: Specialized airtight chambers where temperature, humidity, and ethylene concentration are controlled to trigger the "ripening cycle" (usually 3 to 7 days for bananas).
- **Ethylene scrubbers**: Systems used in storage to remove ethylene gas produced naturally by fruits, preventing "contaminating" other products and causing them to ripen too early.

I.2.3.4. Transport and distribution:

Maintaining the cold chain until the end consumer.