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FST 403

FRUITS AND VEGETABLES TECHNOLOGY

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- Course code: FST 403
- Course title: Fruits and Vegetables Technology
- Course credit load: 3

Series 1: Handling and Processing of Fresh Produce

Series outline

- **1.1 Principles of Handling Fresh Produce**
    - 1.1.1 Post-harvest physiology
    - 1.1.2 Factors affecting quality
- **1.2 Chemical Control of Changes**
    - 1.2.1 Enzymic changes
    - 1.2.2 Non-enzymic changes
- **1.3 Grading, Sorting and Cleaning**
    - 1.3.1 Grading standards
    - 1.3.2 Sorting technologies
    - 1.3.3 Cleaning methods
- **1.4 Peeling, Sampling and Size Reduction**
    - 1.4.1 Peeling techniques
    - 1.4.2 Sampling procedures
    - 1.4.3 Size reduction methods

Introduction

Fresh fruits and vegetables are among the most perishable commodities in the food industry, and their quality can deteriorate rapidly if not handled properly. Imagine a basket of ripe tomatoes left in the sun for a few hours: the colour fades, the texture softens, and the flavour diminishes. This simple scenario highlights why careful handling and processing are essential, not only to maintain nutritional value but also to ensure consumer satisfaction and reduce waste. Within the broader course on Fruits and Vegetables Technology, this Series lays the foundation by focusing on the initial stages of post-harvest management.

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The aim of this Series is to equip you with the knowledge and skills required to handle fresh produce effectively, control chemical changes, and apply appropriate techniques for grading, sorting, cleaning, peeling, sampling, and size reduction.

We shall commence this Series by examining the principles of handling fresh produce, including post-harvest physiology and the factors that influence quality. Next, we will explore the chemical control of enzymic and non-enzymic changes that affect freshness and shelf life. Following that, we will study the processes of grading, sorting, and cleaning, which are vital for preparing produce for further processing. Finally, we will wrap up by considering peeling, sampling, and size reduction methods, which are crucial steps in preparing fruits and vegetables for industrial applications.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define post-harvest physiology and explain its relevance to the handling of fresh produce,
- **SLO 1.2** analyse the factors that affect the quality of fruits and vegetables during handling,
- **SLO 1.3** describe enzymic and non-enzymic changes and demonstrate methods of chemical control,
- **SLO 1.4** explain grading standards and apply sorting and cleaning techniques to fresh produce,
- **SLO 1.5** evaluate peeling techniques and sampling procedures, and
- **SLO 1.6** demonstrate methods of size reduction for fruits and vegetables in processing operations.

1.1 Principles of Handling Fresh Produce

1.1.1 Post-harvest physiology

Fresh fruits and vegetables remain biologically active even after harvest. **Post-harvest physiology** is the study of the biological processes that continue in produce once it has been detached from the parent plant. These processes include **respiration** (the breakdown of sugars to release energy), **transpiration** (loss of water vapour), and **ethylene production** (release of a natural plant hormone that accelerates ripening). Each of these influences the shelf life, flavour, texture, and nutritional value of produce. For instance, bananas ripen quickly due to high ethylene production, while leafy vegetables wilt rapidly because of excessive transpiration.

Fill in the blank: The natural plant hormone that accelerates ripening in fruits is _____.

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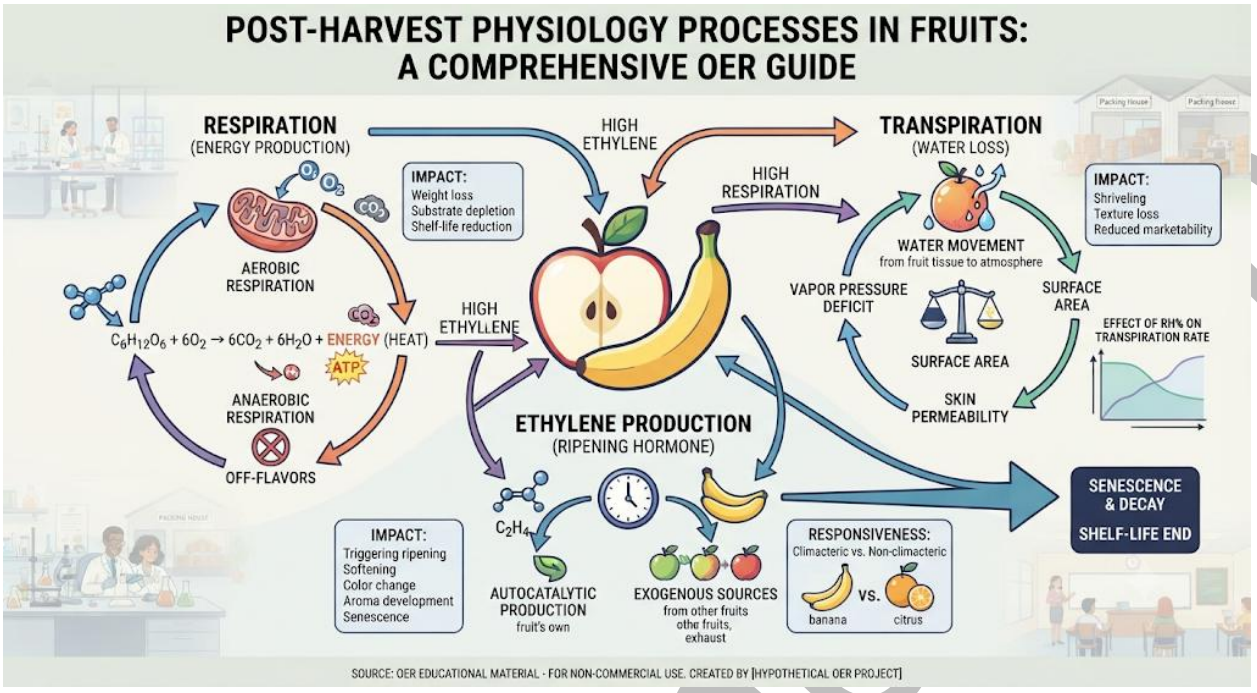

Diagram showing respiration, transpiration, and ethylene production in harvested fruits. *Figure 1.1: Biological processes in post-harvest physiology*

1.1.2 Factors affecting quality

Several external factors determine the quality of fresh produce during handling. **Temperature** is critical, as higher temperatures increase respiration rates and shorten shelf life. **Humidity** also plays a role: low humidity causes wilting, while excessive humidity encourages microbial growth. **Mechanical damage** such as bruising during transport reduces market value and increases susceptibility to decay. Finally, **microbial contamination** can occur when produce is exposed to unsanitary conditions, leading to spoilage and food safety concerns.

Fill in the blank: When vegetables are stored in conditions of low humidity, they are likely to _____.

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Image of bruised apples showing mechanical damage during handling. *Plate 1.1: Mechanical damage in fresh produce*

Pilot questions 1.1

1. What is meant by post-harvest physiology?
2. Which biological process involves the breakdown of sugars to release energy in harvested produce?
3. What natural plant hormone accelerates ripening in fruits?
4. How does high temperature affect the respiration rate of fresh produce?
5. What is one consequence of low humidity during storage of vegetables?

1.2 Chemical Control of Changes

1.2.1 Enzymic changes

Fresh fruits and vegetables undergo **enzymic changes**, which are chemical reactions catalysed by enzymes naturally present in plant tissues. **Enzymes** are biological catalysts that speed up reactions without being consumed. In produce, enzymes such as **polyphenol oxidase** cause browning when tissues are cut or bruised, while **pectinase** softens fruit texture during ripening. These changes can reduce consumer appeal and shorten shelf life. To control enzymic activity, processors use methods such as blanching, chemical inhibitors, or modified storage conditions.

Fill in the blank: The enzyme responsible for browning in cut apples is _____.

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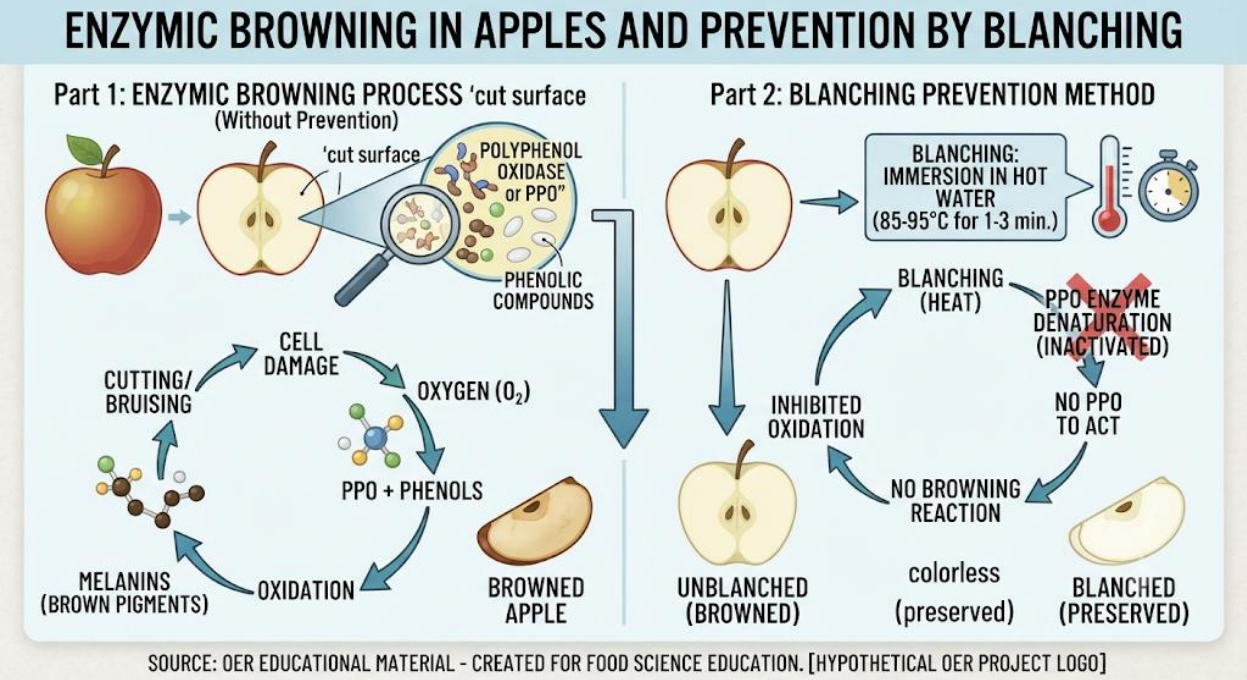

Diagram showing enzymic browning in apples and its prevention by blanching. *Figure 1.2: Enzymic browning and control methods*

1.2.2 Non-enzymic changes

In addition to enzymic activity, fruits and vegetables also experience **non-enzymic changes**, which are chemical reactions not driven by enzymes. A common example is the **Maillard reaction**, where reducing sugars react with amino acids to produce brown pigments and flavour compounds. Another example is **oxidation**, where exposure to oxygen leads to colour and nutrient loss. These changes can occur during handling, storage, or processing, and they influence both the nutritional and sensory qualities of produce. Control measures include reducing oxygen exposure, using antioxidants, and maintaining appropriate storage conditions.

Fill in the blank: The reaction between reducing sugars and amino acids that produces brown pigments is called _____.

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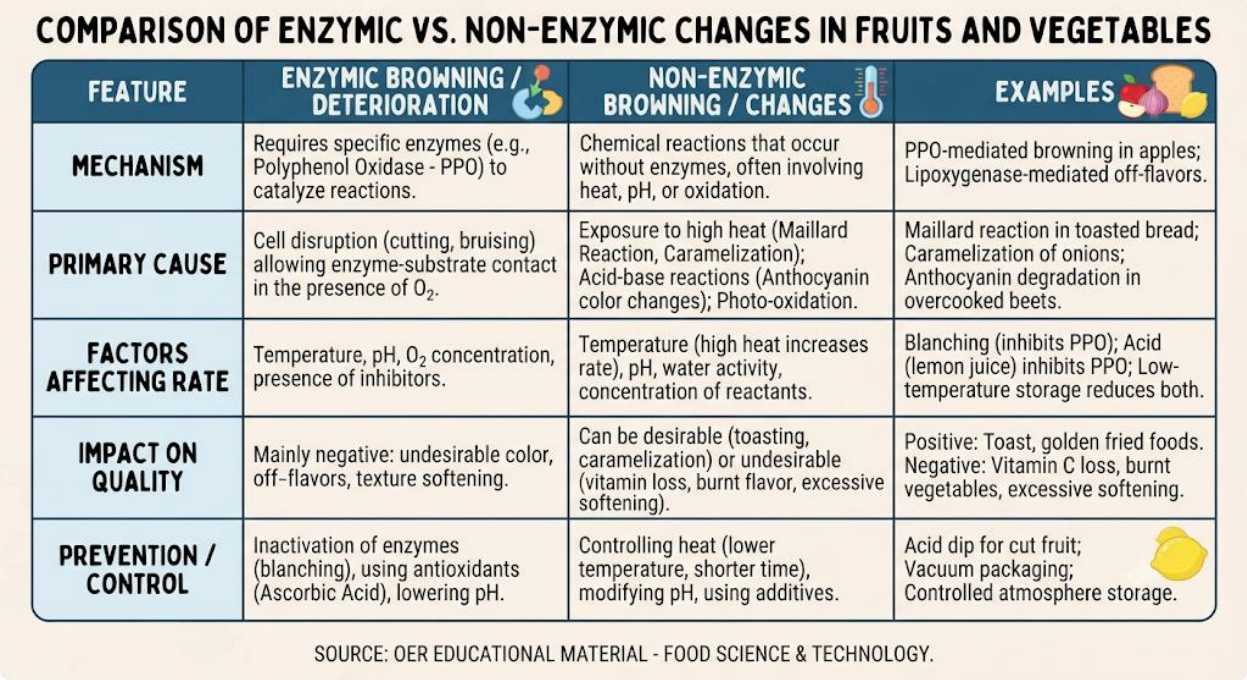

COMPARISON OF ENZYMIC VS. NON-ENZYMIC CHANGES IN FRUITS AND VEGETABLES

FEATURE	ENZYMIC BROWNING / DETERIORATION	NON-ENZYMIC BROWNING / CHANGES	EXAMPLES
MECHANISM	Requires specific enzymes (e.g., Polyphenol Oxidase - PPO) to catalyze reactions.	Chemical reactions that occur without enzymes, often involving heat, pH, or oxidation.	PPO-mediated browning in apples; Lipoxygenase-mediated off-flavors.
PRIMARY CAUSE	Cell disruption (cutting, bruising) allowing enzyme-substrate contact in the presence of O_2.	Exposure to high heat (Maillard Reaction, Caramelization); Acid-base reactions (Anthocyanin color changes); Photo-oxidation.	Maillard reaction in toasted bread; Caramelization of onions; Anthocyanin degradation in overcooked beets.
FACTORS AFFECTING RATE	Temperature, pH, O_2 concentration, presence of inhibitors.	Temperature (high heat increases rate), pH, water activity, concentration of reactants.	Blanching (inhibits PPO); Acid (lemon juice) inhibits PPO; Low-temperature storage reduces both.
IMPACT ON QUALITY	Mainly negative: undesirable color, off-flavors, texture softening.	Can be desirable (toasting, caramelization) or undesirable (vitamin loss, burnt flavor, excessive softening).	Positive: Toast, golden fried foods. Negative: Vitamin C loss, burnt vegetables, excessive softening.
PREVENTION / CONTROL	Inactivation of enzymes (blanching), using antioxidants (Ascorbic Acid), lowering pH.	Controlling heat (lower temperature, shorter time), modifying pH, using additives.	Acid dip for cut fruit; Vacuum packaging; Controlled atmosphere storage.

SOURCE: OER EDUCATIONAL MATERIAL - FOOD SCIENCE & TECHNOLOGY.

Box 1.1: Key differences between enzymic and non-enzymic changes

- Enzymic changes: catalysed by enzymes, e.g., browning by polyphenol oxidase.
- Non-enzymic changes: occur without enzymes, e.g., Maillard reaction and oxidation.

Pilot questions 1.2

1. What are enzymes and how do they affect fresh produce?
2. Which enzyme causes browning in cut apples?
3. What is the Maillard reaction and why is it significant in food processing?
4. How does oxidation affect the nutritional quality of fruits and vegetables?
5. Name one method used to control enzymic changes in fresh produce.

1.3 Grading, Sorting and Cleaning

1.3.1 Grading standards

Grading refers to the classification of fruits and vegetables based on specific quality parameters such as size, colour, shape, and absence of defects. **Grading standards** are guidelines established to ensure uniformity and consistency in produce quality. For example, citrus fruits may be graded according to diameter and skin colour, while tomatoes are graded based on ripeness and firmness. Grading helps processors and retailers meet consumer expectations and comply with regulatory requirements.

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Fill in the blank: Fruits and vegetables are classified into categories based on _____.

GRADING STANDARDS FOR SELECTED FRUITS: CITRUS, TOMATOES, AND BANANAS

GRADE FACTOR	CITRUS (e.g., Oranges)	TOMATOES (e.g., Fresh Market)	BANANAS (e.g., Export Cavendish)	COMMON DEFECTS/TOLERANCES
SIZE/WEIGHT	• 60mm-95mm Count per standard carton	• Small 100g-250g • Medium 100g-300g • Large 95g-250g • Extra Large: 120g-250g	• Grade A: >19cm • Grade B: >19cm • Grade C: >19cm	• Grade A: >19cm • Grade B: >18cm • Grade A: >18cm
COLOR/MATURITY	Uniform color: 90%+ characteristic orange color	• Mature Green • Turning • Turning to Light Red • Red	• Full ¾ green • Full ¾ green • Red	• Full ¾ green • Full ¾ green • Full ¾ green
SHAPE & APPEARANCE	• Well-formed, characteristic shape	• Well-developed, not puffy or ridged	• Well-formed, not excessively curved	• Well-formed, not excessively curved
FIRMNESS	• Firm, not soft	• Firm, not mushy	• Firm	• Firm, no sign of over-ripening
BLEMISHES/DEFECTS (TOLERANCES)	• U.S. No. 1: 5% tolerance • U.S. No. 1: 5% tolerance • U.S. No. 1: 5% tolerance • U.S. No. 1: 5% tolerance • U.S. No. 1: 5% tolerance	• No. 1: scars <10% of surface • No. 2: scars • No. 3: clered surface • No. 4: crash surface • No. 5: red		• Grade A: no scars • Grade 2: no scars • Grade 3: de storation • Grade 4: scars • Grade 5: no scars
GRADE CATEGORIES (ILLUSTRATIVE)	• U.S. Fancy • U.S. No. 1 • U.S. No. 2	• U.S. No. 1 • U.S. No. 2 • U.S. No. 3	• Extra Premium • Premium • Class 1	

SOURCE: OER EDUCATIONAL MATERIAL - GENERAL GUIDELINES FOR GRADING FRUITS. NOT FOR COMMERCIAL USE.

Table 1.1: Examples of grading standards for selected fruits and vegetables

1.3.2 Sorting technologies

Sorting is the process of separating produce into groups according to specific attributes. Traditional sorting methods rely on manual inspection, while modern systems use **mechanical** or **electronic technologies**. Mechanical sorting may involve sieves or rollers that separate produce by size, whereas electronic sorting uses sensors to detect colour, weight, or defects. Automated sorting improves efficiency, reduces labour costs, and ensures greater accuracy.

Fill in the blank: Modern sorting systems often use _____ to detect colour and defects in produce.

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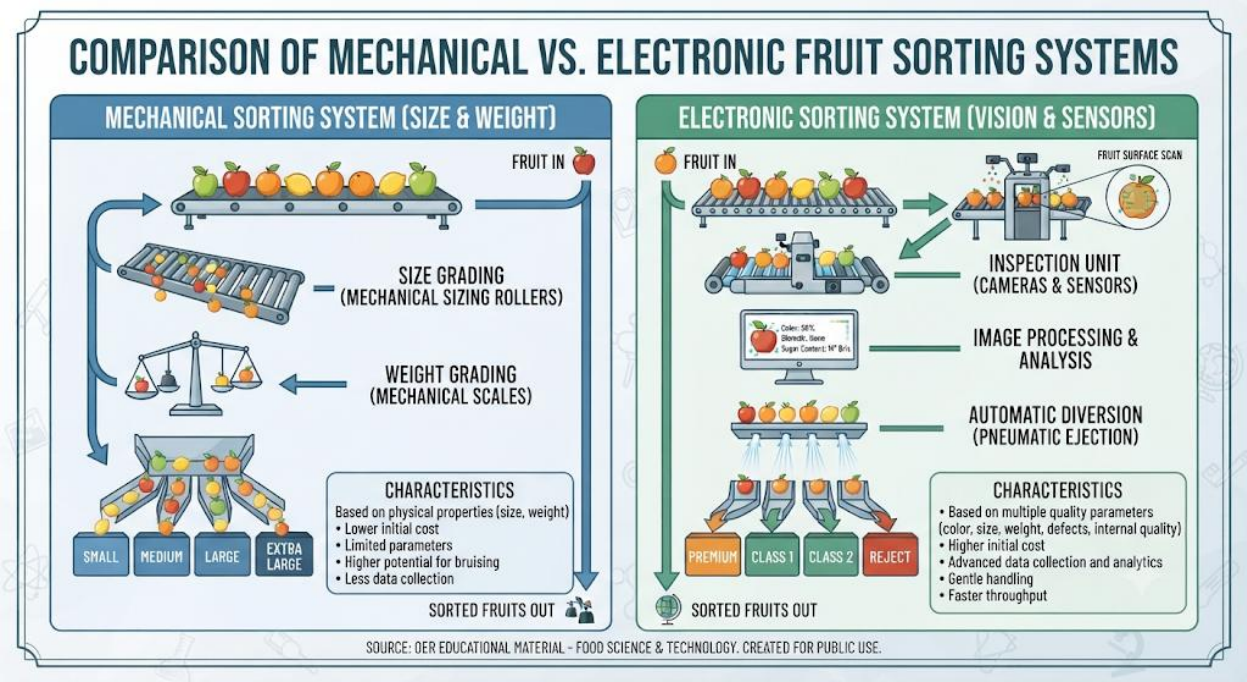

Diagram of mechanical and electronic sorting systems for fruits. *Figure 1.3: Sorting technologies in fruit processing*

1.3.3 Cleaning methods

Cleaning is the removal of dirt, pesticide residues, and microbial contaminants from fresh produce. Methods include **washing** with clean water, **chlorination** to reduce microbial load, and **brushing** to remove soil particles. In industrial settings, cleaning may involve high-pressure sprays or ultrasonic systems. Proper cleaning is essential for food safety and quality assurance, as contaminated produce can lead to spoilage and health risks.

Fill in the blank: One common chemical used to reduce microbial load during cleaning is _____.

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Image of industrial washing and cleaning of fresh vegetables. *Plate 1.2: Cleaning methods in vegetable processing*

Pilot questions 1.3

1. What is grading and why is it important in fruit and vegetable processing?
2. Name two parameters used to grade citrus fruits.
3. What is the difference between mechanical and electronic sorting systems?
4. Which modern technology is used to detect colour and defects in produce?
5. Mention one chemical commonly used in cleaning fresh produce.

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1.4 Peeling, Sampling and Size Reduction

1.4.1 Peeling techniques

Peeling is the removal of the outer covering of fruits and vegetables to improve appearance, texture, and safety. The peel often contains dirt, pesticide residues, or tough fibres that are undesirable in processed products. Techniques include **manual peeling** using knives, **mechanical peeling** with machines, and **chemical peeling** using solutions such as caustic soda to loosen skins. Steam peeling is another modern method that uses high-pressure steam to soften and detach the peel.

Fill in the blank: The peeling method that uses high-pressure steam to soften skins is called _____.

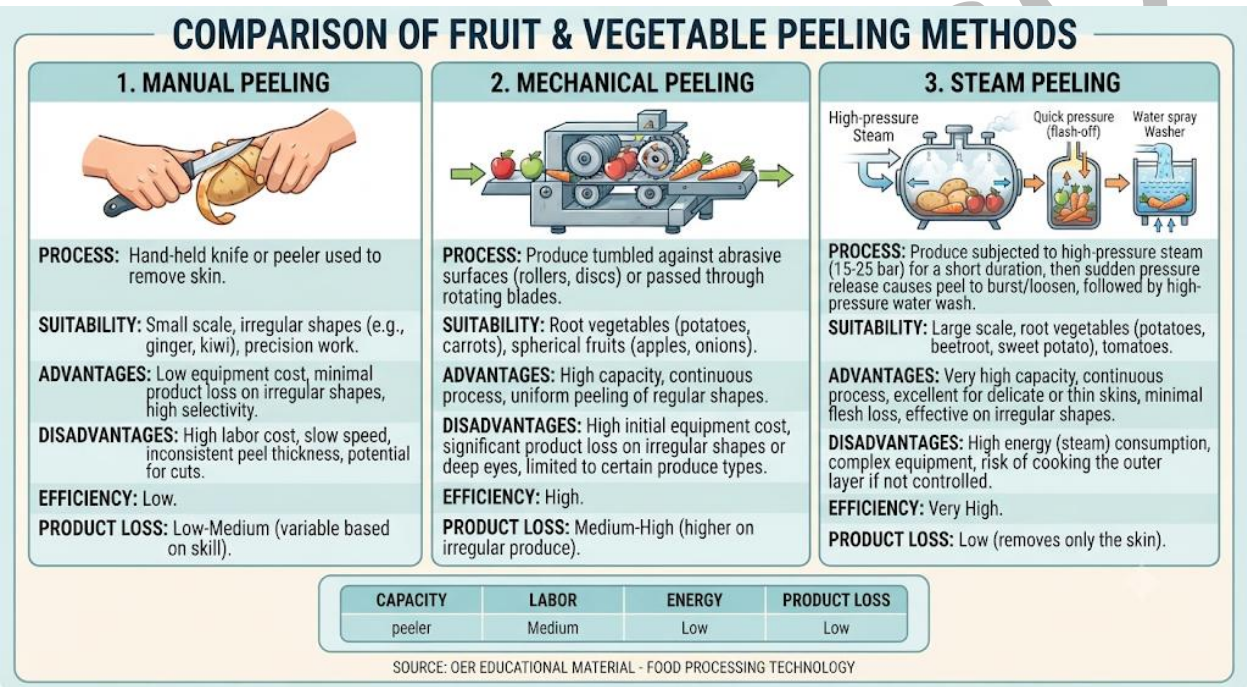

Diagram showing manual, mechanical, and steam peeling methods. *Figure 1.4: Peeling techniques in fruit and vegetable processing*

1.4.2 Sampling procedures

Sampling refers to the process of selecting a representative portion of produce for quality assessment. Proper sampling ensures that the evaluation reflects the overall batch. Techniques include **random sampling**, where items are selected without bias, and **systematic sampling**, where items are chosen at regular intervals. Sampling is critical for detecting defects, measuring moisture content, and assessing compliance with grading standards.

Fill in the blank: The sampling method that selects items at regular intervals is called _____.

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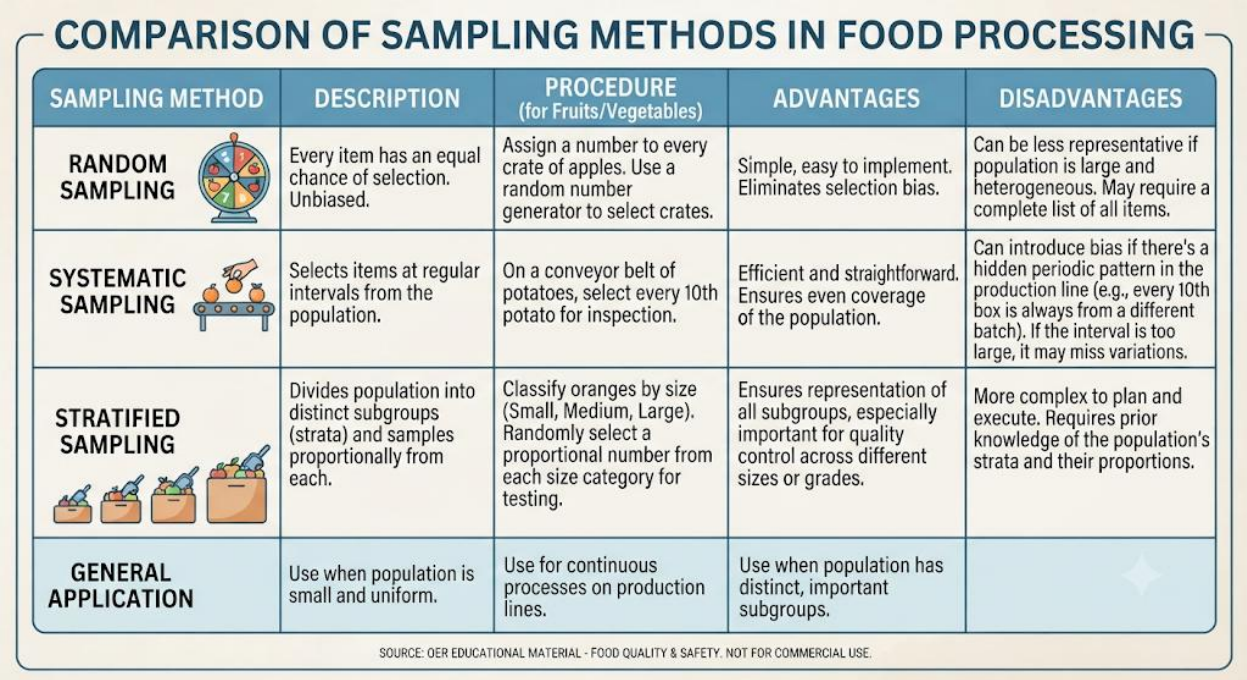

COMPARISON OF SAMPLING METHODS IN FOOD PROCESSING

SAMPLING METHOD	DESCRIPTION	PROCEDURE (for Fruits/Vegetables)	ADVANTAGES	DISADVANTAGES
RANDOM SAMPLING	Every item has an equal chance of selection. Unbiased.	Assign a number to every crate of apples. Use a random number generator to select crates.	Simple, easy to implement. Eliminates selection bias.	Can be less representative if population is large and heterogeneous. May require a complete list of all items.
SYSTEMATIC SAMPLING	Selects items at regular intervals from the population.	On a conveyor belt of potatoes, select every 10th potato for inspection.	Efficient and straightforward. Ensures even coverage of the population.	Can introduce bias if there's a hidden periodic pattern in the production line (e.g., every 10th box is always from a different batch). If the interval is too large, it may miss variations.
STRATIFIED SAMPLING	Divides population into distinct subgroups (strata) and samples proportionally from each.	Classify oranges by size (Small, Medium, Large). Randomly select a proportional number from each size category for testing.	Ensures representation of all subgroups, especially important for quality control across different sizes or grades.	More complex to plan and execute. Requires prior knowledge of the population's strata and their proportions.
GENERAL APPLICATION	Use when population is small and uniform.	Use for continuous processes on production lines.	Use when population has distinct, important subgroups.	

SOURCE: OER EDUCATIONAL MATERIAL - FOOD QUALITY & SAFETY. NOT FOR COMMERCIAL USE.

Box 1.2: Key sampling methods in fruit and vegetable processing

- Random sampling: unbiased selection of items.
- Systematic sampling: items chosen at fixed intervals.
- Stratified sampling: items grouped and sampled by category.

1.4.3 Size reduction methods

Size reduction is the process of cutting, slicing, dicing, or grinding fruits and vegetables into smaller pieces. This step facilitates uniform cooking, drying, or blending during processing. Common methods include **slicing** for fruits like mangoes, **dicing** for vegetables such as carrots,

and **grinding** for products like tomato paste. Size reduction improves efficiency, enhances product consistency, and prepares raw materials for further processing.

Fill in the blank: Cutting vegetables into small cubes is known as _____.

Image of diced carrots and sliced mangoes prepared for processing. *Plate 1.3: Examples of size reduction in fruits and vegetables*

Pilot questions 1.4

1. What is peeling and why is it important in fruit and vegetable processing?
2. Name one chemical used in chemical peeling.
3. Which sampling method involves selecting items at fixed intervals?
4. Why is sampling important in quality assessment of produce?
5. What is the term used for cutting vegetables into small cubes?

Series Summary

This Series has introduced you to the fundamental aspects of handling and processing fresh fruits and vegetables, which form the basis of effective post-harvest management. We began by examining post-harvest physiology and the factors that influence quality, then moved on to the chemical control of enzymic and non-enzymic changes that affect freshness and shelf life. Following that, we explored grading standards, sorting technologies, and cleaning methods, which are essential for preparing produce for further processing. Finally, we considered peeling

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techniques, sampling procedures, and size reduction methods, which are critical steps in industrial applications.

By engaging with these topics, you should now be able to define post-harvest physiology, analyse quality factors, describe enzymic and non-enzymic changes, explain grading and sorting processes, evaluate peeling and sampling methods, and demonstrate size reduction techniques. These abilities directly align with the Series Learning Outcomes and provide you with a strong foundation for subsequent Series in this course.

Glossary of Terms

- **Cleaning**: The removal of dirt, pesticide residues, and microbial contaminants from fresh produce.
- **Enzymes**: Biological catalysts that speed up chemical reactions without being consumed.
- **Enzymic changes**: Chemical reactions in produce catalysed by enzymes, such as browning caused by polyphenol oxidase.
- **Grading**: The classification of fruits and vegetables based on quality parameters such as size, colour, and absence of defects.
- **Mechanical damage**: Physical injury to produce, such as bruising, which reduces quality and increases susceptibility to decay.
- **Non-enzymic changes**: Chemical reactions in produce not driven by enzymes, such as the Maillard reaction and oxidation.
- **Peeling**: The removal of the outer covering of fruits and vegetables to improve appearance and safety.
- **Post-harvest physiology**: The study of biological processes such as respiration, transpiration, and ethylene production that continue after harvest.
- **Sampling**: The process of selecting a representative portion of produce for quality assessment.
- **Size reduction**: Cutting, slicing, dicing, or grinding fruits and vegetables into smaller pieces for processing.
- **Sorting**: The separation of produce into groups based on attributes such as size, colour, or defects.

Concept Check Questions [Series 1]

Objective questions

1. Which enzyme is responsible for browning in cut apples? (Linked to SLO 1.3)
2. What natural plant hormone accelerates ripening in fruits? (Linked to SLO 1.1)

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3. Which sampling method involves selecting items at fixed intervals? (Linked to SLO 1.5)

Short-answer questions

4. Explain why mechanical damage reduces the market value of fruits and vegetables. (Linked to SLO 1.2)
5. Describe one method used to control enzymic changes in fresh produce. (Linked to SLO 1.3)

Long-answer questions

6. Analyse the importance of grading, sorting, and cleaning in preparing fruits and vegetables for processing. (Linked to SLO 1.4)
    - *Basic response*: Grading ensures uniformity, sorting separates produce by attributes, and cleaning removes contaminants, all of which improve quality and safety.
    - *Value-added response*: Beyond quality assurance, these processes enhance efficiency in industrial operations, reduce waste, and ensure compliance with international standards.
7. Evaluate the role of peeling, sampling, and size reduction in fruit and vegetable technology. (Linked to SLO 1.5 and SLO 1.6)
    - *Basic response*: Peeling removes unwanted outer layers, sampling ensures quality assessment, and size reduction prepares produce for processing.
    - *Value-added response*: These steps also influence consumer acceptance, product consistency, and the efficiency of downstream processes such as drying, canning, and blending.

Answers to Pilot Questions [Series 1]

Part 1.1

- Respiration.
- Ethylene.
- It increases respiration rate.
- Wilting.
- It reduces quality and increases susceptibility to decay.

Part 1.2

- Enzymes are biological catalysts that speed up reactions.

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- Polyphenol oxidase.
- Reaction between reducing sugars and amino acids producing brown pigments.
- Loss of nutrients and colour.
- Blanching.

Part 1.3

- Classification of produce based on quality parameters.
- Diameter and skin colour.
- Mechanical uses sieves or rollers, electronic uses sensors.
- Sensors.
- Chlorine.

Part 1.4

- Removal of outer covering to improve safety and appearance.
- Caustic soda.
- Systematic sampling.
- Ensures representative quality assessment.
- Dicing.

References and Attributions [Series 1]

- Suggested OER sources for diagrams and tables:
    - “Post-harvest physiology diagram OER”
    - “Enzymic browning apples diagram OER”
    - “Fruit vegetable grading standards OER table”
    - “Fruit sorting technologies diagram OER”
    - “Vegetable cleaning industrial washing OER image”
    - “Fruit vegetable peeling methods diagram OER”
    - “Sampling methods fruits vegetables OER table”
    - “Size reduction fruits vegetables diced sliced OER image”
- AI prompt suggestions used for illustrations:

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- Diagram of post-harvest physiology processes in fruits including respiration, transpiration, and ethylene production.
- Diagram of enzymic browning in apples with blanching prevention.
- Table showing grading standards for citrus, tomatoes, and bananas.
- Diagram comparing mechanical and electronic sorting systems for fruits.
- Photograph of industrial washing and cleaning of vegetables.
- Diagram comparing manual, mechanical, and steam peeling methods.
- Table summarising random, systematic, and stratified sampling methods in food processing.
- Photograph of diced carrots and sliced mangoes for processing.

All definitions and explanations are based on the instructional content developed for Series 1: Handling and Processing of Fresh Produce.

Series 2: Raw Materials and Botanical Characteristics

Series outline

- **2.1 Classification of Raw Materials**
  - [2.1.1 Citrus fruits]
  - [2.1.2 Mangoes]
  - [2.1.3 Onions]
  - [2.1.4 Bananas]
- **2.2 Botanical characteristics**
  - [2.2.1 Morphological features]
  - [2.2.2 Physiological traits]
- **2.3 Composition of fruits and vegetables**
  - [2.3.1 Nutritional components]
  - [2.3.2 Phytochemicals and pigments]

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- **2.4 Harvesting practices and initial handling**
    - [2.4.1 Harvesting methods]
    - [2.4.2 Post-harvest handling techniques]

Introduction

Fruits and vegetables form the backbone of the food industry, and each type of raw material has unique features that determine how it is handled, processed, and preserved. From the vibrant colours of citrus fruits to the pungent aroma of onions, these characteristics influence consumer acceptance and industrial applications. By studying their botanical traits and composition, you will gain insight into why certain crops are harvested in specific ways and how their nutritional and chemical properties affect processing outcomes.

The aim of this Series is to familiarise you with the classification of key raw materials, their botanical characteristics, composition, and the practical aspects of harvesting and initial handling.

We shall commence this Series by classifying raw materials such as citrus fruits, mangoes, onions, and bananas. Next, we will explore their botanical characteristics, focusing on morphological and physiological traits. Following that, we will examine the composition of fruits and vegetables, including nutritional components and pigments. Finally, we will wrap up by considering harvesting practices and initial handling techniques that ensure quality and reduce losses.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** classify major fruits and vegetables used in the industry, including citrus, mangoes, onions, and bananas,
- **SLO 2.2** describe the morphological and physiological traits of fruits and vegetables,
- **SLO 2.3** analyse the nutritional composition and phytochemicals present in fruits and vegetables,
- **SLO 2.4** explain harvesting methods and evaluate post-harvest handling techniques.

2.1 Classification of Raw Materials

2.1.1 Citrus fruits

Citrus fruits are a group of fruits belonging to the genus *Citrus*, including oranges, lemons, limes, and grapefruits. They are characterised by their bright colours, juicy pulp, and high vitamin C content. Citrus fruits are widely used in juice production, flavouring, and preservation. Their thick peel protects the inner pulp but also requires careful handling during processing.

Fill in the blank: The vitamin most abundant in citrus fruits is _____.

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Image of different citrus fruits such as oranges, lemons, and grapefruits. *Plate 2.1: Examples of citrus fruits*

2.1.2 Mangoes

Mangoes are tropical fruits belonging to the genus *Mangifera*. They are known for their sweet flavour, vibrant colour, and high sugar content. Mangoes are processed into juices, jams, and dried slices. Their soft texture makes them prone to mechanical damage, so careful handling is essential.

Fill in the blank: Mangoes are commonly processed into _____ and dried slices.

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Image of ripe mangoes and processed mango juice. *Plate 2.2: Mangoes and mango juice*

2.1.3 Onions

Onions are bulb vegetables belonging to the genus *Allium*. They are valued for their pungent flavour and are widely used in cooking and food processing. Onions contain sulphur compounds that contribute to their aroma and flavour. They are processed into dehydrated flakes, powders, and pastes.

Fill in the blank: The compounds responsible for the pungent flavour of onions are _____ compounds.

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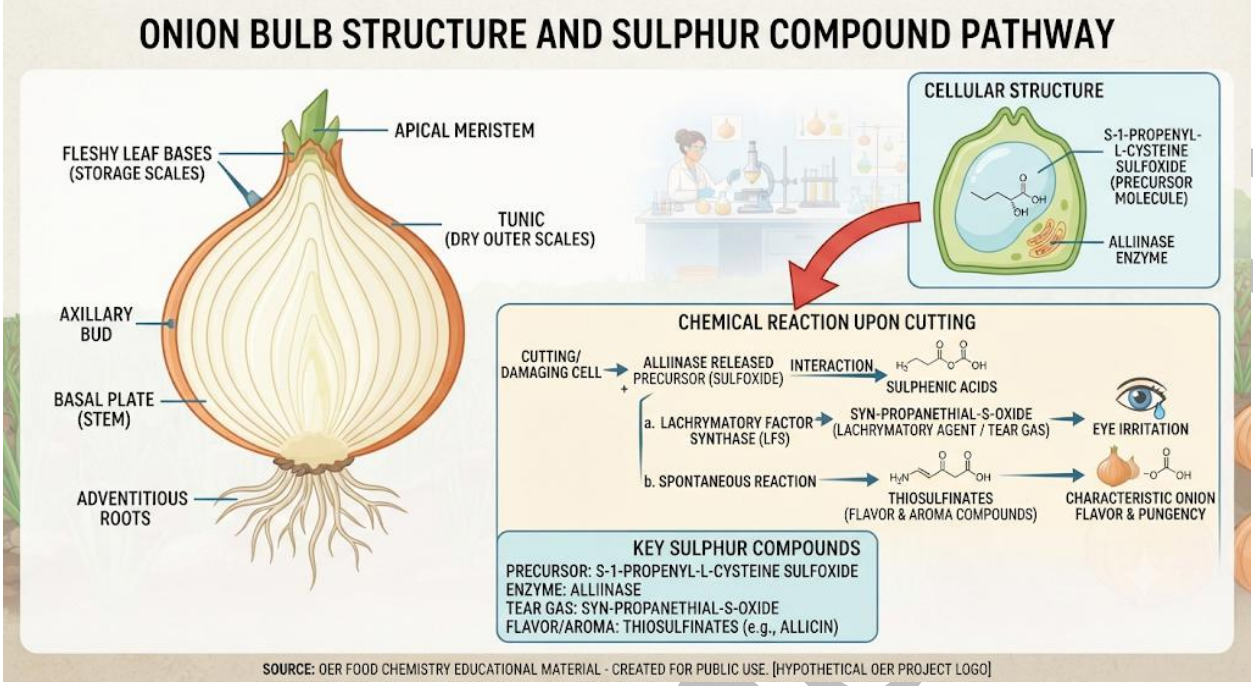

Diagram showing onion bulb structure and sulphur compounds. *Figure 2.1: Onion bulb and flavour compounds*

2.1.4 Bananas

Bananas are fruits belonging to the genus *Musa*. They are rich in carbohydrates, particularly starch, which converts to sugars during ripening. Bananas are consumed fresh or processed into chips, flour, and purees. Their high ethylene production makes them ripen quickly, requiring controlled storage conditions.

Fill in the blank: The carbohydrate in bananas that converts to sugars during ripening is _____.

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Image of ripe bananas and banana chips. *Plate 2.3: Bananas and banana chips*

Pilot questions 2.1

1. Which vitamin is most abundant in citrus fruits?
2. Mangoes are commonly processed into which products?
3. What compounds are responsible for the pungent flavour of onions?
4. Which carbohydrate in bananas converts to sugars during ripening?
5. Why do bananas require controlled storage conditions?

2.2 Botanical Characteristics

2.2.1 Morphological features

Morphological features refer to the external structures of fruits and vegetables that can be observed directly, such as shape, size, colour, and texture. These features are important for identification, grading, and consumer acceptance. For example, citrus fruits are typically round with a thick peel, mangoes have an oval shape with smooth skin, onions form bulbs with layered scales, and bananas are elongated with a peel that changes colour during ripening. These visible traits often determine how produce is marketed and processed.

Fill in the blank: The external structures of fruits and vegetables that can be observed directly are called _____ features.

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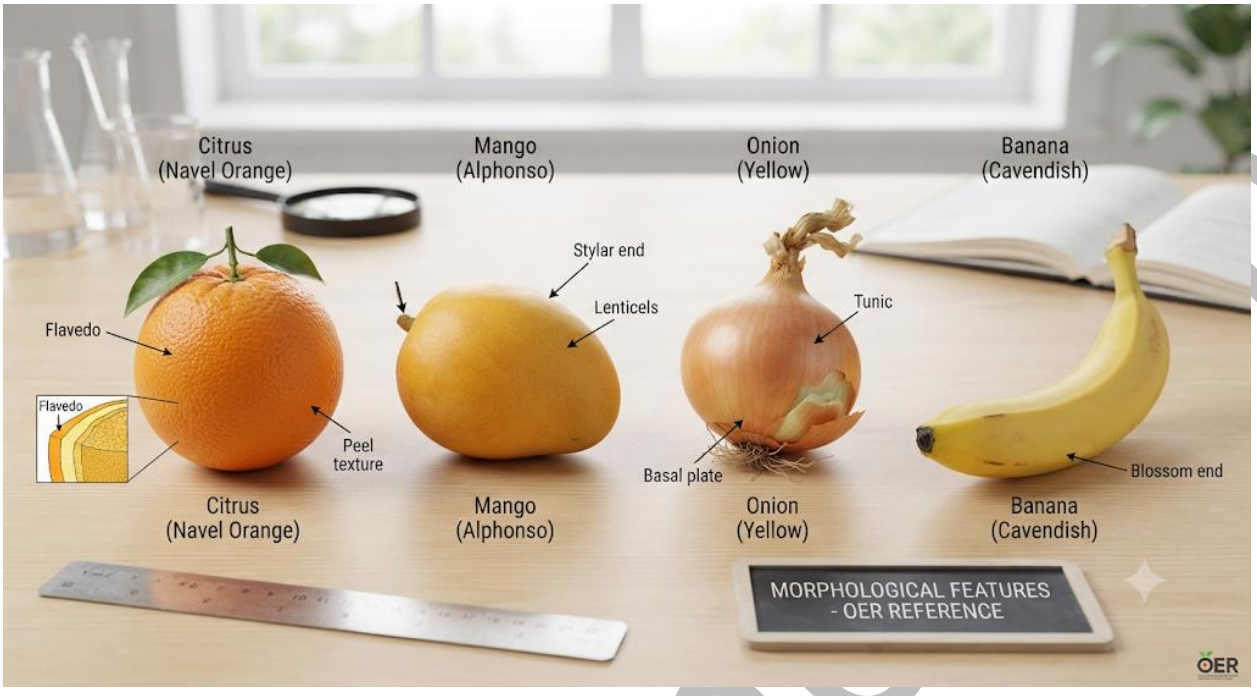

Image showing citrus, mango, onion, and banana highlighting their external structures. *Plate 2.4: Morphological features of selected fruits and vegetables*

2.2.2 Physiological traits

Physiological traits are the internal biological processes that influence the growth, ripening, and storage behaviour of fruits and vegetables. These include respiration rate, transpiration, and ethylene production. For instance, bananas have a high respiration rate and produce large amounts of ethylene, which accelerates ripening. Onions, on the other hand, have low respiration rates and can be stored for longer periods under proper conditions. Understanding these traits helps in designing appropriate storage and preservation methods.

Fill in the blank: The internal biological processes that influence ripening and storage behaviour are called _____ traits.

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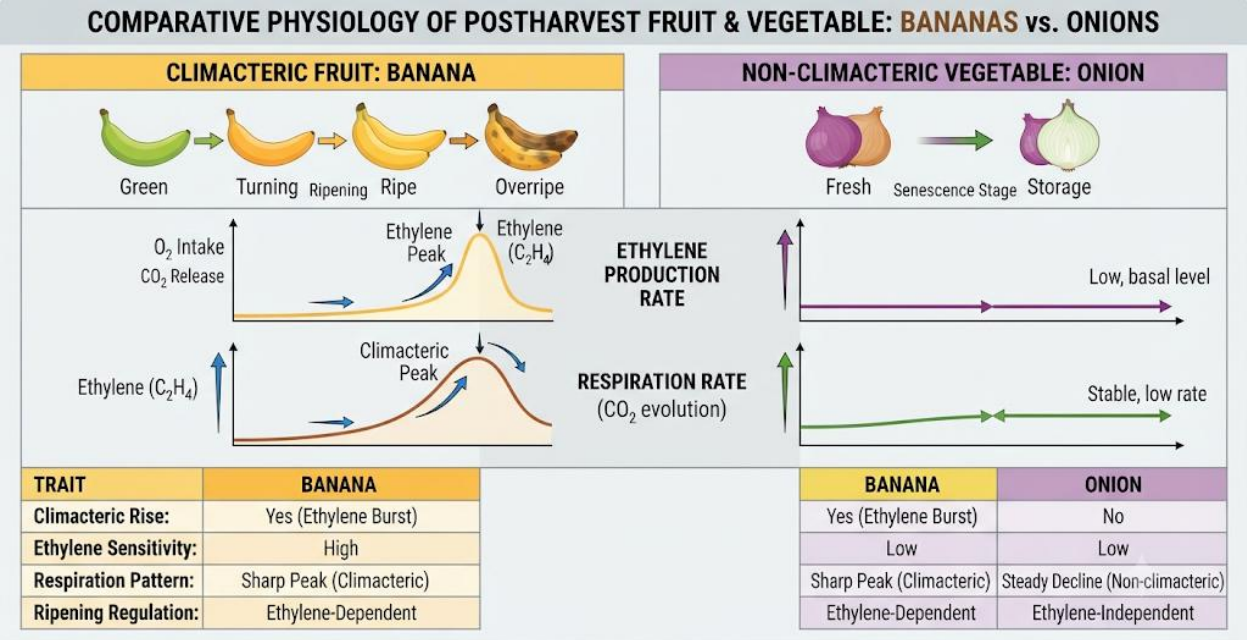

Source: *Plant Physiology, Postharvest Biology (OER Educational Diagram)*

Diagram showing respiration and ethylene production in bananas compared to onions. *Figure 2.2: Physiological traits influencing ripening and storage*

Pilot questions 2.2

1. What are morphological features in fruits and vegetables?
2. Give one example of a morphological feature in citrus fruits.
3. What are physiological traits and why are they important?
4. Which fruit has a high respiration rate and produces large amounts of ethylene?
5. Why can onions be stored for longer periods compared to bananas?

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2.3 Composition of Fruits and Vegetables

2.3.1 Nutritional components

Nutritional components are the essential substances in fruits and vegetables that contribute to human health. These include **carbohydrates**, which provide energy, **proteins**, which support growth and repair, and **lipids**, which are present in small amounts in some fruits like avocados. Vitamins and minerals are also abundant: citrus fruits are rich in vitamin C, bananas provide potassium, and leafy vegetables supply iron and folate. The balance of these nutrients determines the dietary value of each crop and influences how they are used in food processing.

Fill in the blank: The mineral most abundant in bananas that supports muscle function is _____.

NUTRITIONAL COMPOSITION OF SELECTED FRUITS AND VEGETABLES (PER 100g EDIBLE PORTION)

NUTRIENT CATEGORY	CITRUS (Oranges/Lemons)	MANGOES	ONIONS	BANANAS
CARBOHYDRATES	Total Sugars Dietary Fiber	Total Sugars Dietary Fiber	Dietary Fiber Sugars	High Total Sugars, Starch, Dietary Fiber
PROTEINS	Low	Low	Low	Low
VITAMINS	High Vitamin C Folate	High Vitamin A Vitamin C	Vitamin C Vitamin B6	Vitamin B6 Vitamin C
KEY COMPONENTS	Potassium Calcium	Potassium Copper	Potassium Manganese	High Potassium Magnesium
APPROX. QUANTITY (per 100g)				
HEALTH BENEFITS	Immune Support Collagen Synthesis	Eye Health Antioxidant Protection. Protection	Anti-inflammatory Heart Health	Energy Boost Blood Pressure Regulation

Source: Compiled from USDA FoodData Central (OER Educational Resource)

Table 2.1: Nutritional components of selected fruits and vegetables

2.3.2 Phytochemicals and pigments

Phytochemicals are naturally occurring compounds in plants that provide health benefits beyond basic nutrition. Examples include **flavonoids**, which act as antioxidants, and **carotenoids**, which give fruits and vegetables their bright colours. **Pigments** are specific phytochemicals responsible for colour, such as chlorophyll in green vegetables, anthocyanins in berries, and lycopene in tomatoes. These compounds not only enhance visual appeal but also contribute to disease prevention and overall wellness.

Fill in the blank: The red pigment found in tomatoes that acts as an antioxidant is called _____.

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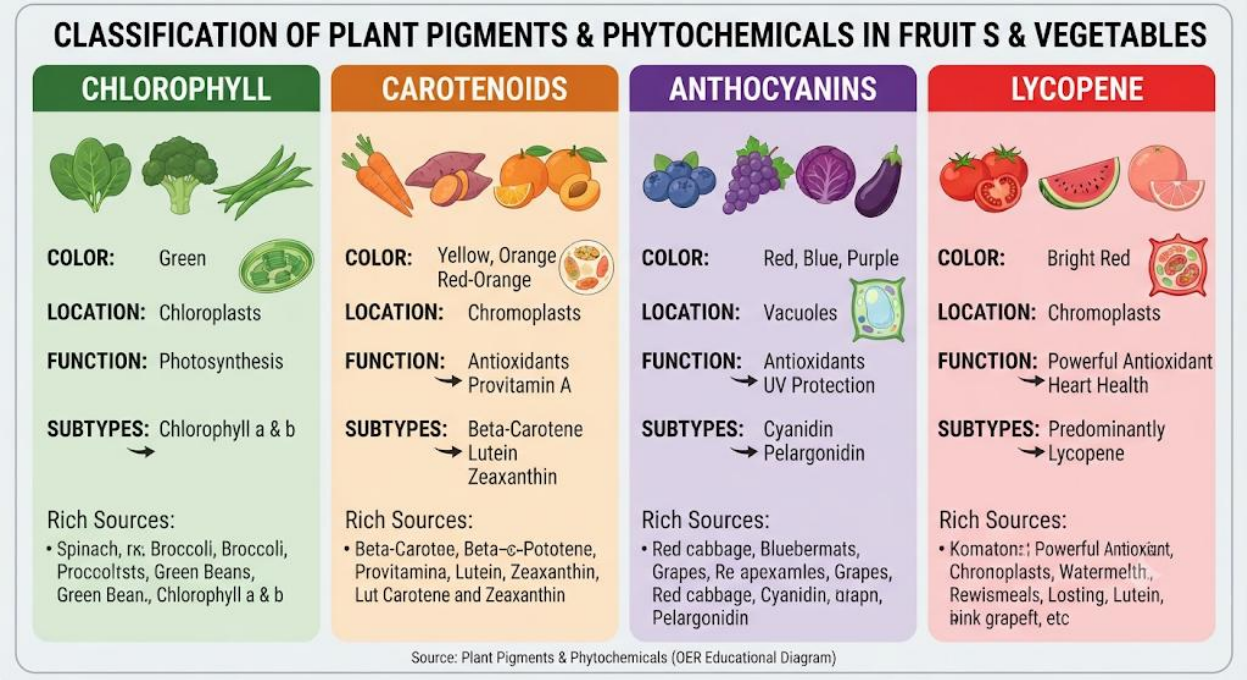

Diagram showing major pigments in fruits and vegetables (chlorophyll, anthocyanins, carotenoids, lycopene). *Figure 2.3: Pigments and phytochemicals in fruits and vegetables*

Pilot questions 2.3

1. What are nutritional components in fruits and vegetables?
2. Which mineral is abundant in bananas and supports muscle function?
3. Give one example of a phytochemical and its health benefit.
4. Name the pigment responsible for the red colour in tomatoes.
5. Why are phytochemicals important in fruits and vegetables?

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2.4 Harvesting Practices and Initial Handling

2.4.1 Harvesting methods

Harvesting methods are the techniques used to collect fruits and vegetables from the field at the appropriate stage of maturity. The choice of method depends on the type of crop, its intended use,

and the scale of production. For example, citrus fruits are often hand-picked to avoid bruising, while onions may be mechanically harvested using specialised equipment. Bananas are harvested in bunches and require careful handling to prevent damage. Proper harvesting ensures that produce retains its quality and nutritional value.

Fill in the blank: Citrus fruits are usually harvested by _____ to avoid bruising.

[Insert plate here] Image of workers hand-picking citrus fruits in an orchard. *Plate 2.5: Hand harvesting of citrus fruits* AI prompt suggestion: "Photograph of workers hand-picking citrus fruits in an orchard" Search string: "citrus fruit harvesting hand picking OER image"

2.4.2 Post-harvest handling techniques

Post-harvest handling techniques are the practices applied immediately after harvesting to maintain quality and reduce losses. These include sorting, cleaning, packaging, and transportation. For example, mangoes may be sorted by ripeness before packaging, onions are cured to reduce moisture content, and bananas are transported in temperature-controlled containers to slow ripening. Effective post-harvest handling reduces spoilage, ensures food safety, and improves marketability.

Fill in the blank: Bananas are often transported in _____ containers to slow ripening.

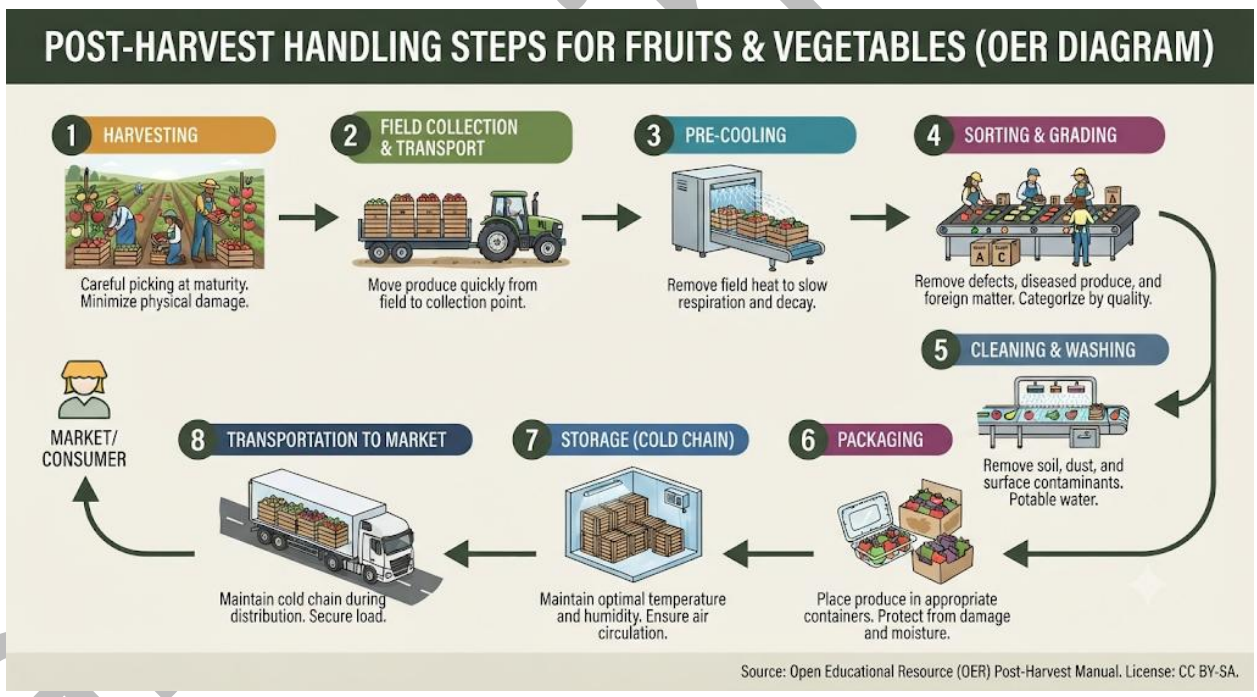

Diagram showing post-harvest handling steps: sorting, cleaning, packaging, and transportation.
Figure 2.4: Post-harvest handling techniques for fruits and vegetables

Pilot questions 2.4

1. What are harvesting methods and why are they important?
2. How are citrus fruits usually harvested to avoid bruising?

3. Give one example of a crop that is mechanically harvested.
4. What is curing in onions and why is it done?
5. Why are bananas transported in temperature-controlled containers?

Series Summary

This Series has provided a comprehensive overview of raw materials and their botanical characteristics, which are central to fruit and vegetable technology. We began by classifying key crops such as citrus fruits, mangoes, onions, and bananas, then examined their morphological and physiological traits. Following that, we explored the nutritional composition and phytochemicals that contribute to health and colour. Finally, we considered harvesting methods and post-harvest handling techniques that preserve quality and reduce losses.

By engaging with these topics, you should now be able to classify major fruits and vegetables, describe their botanical features, analyse their nutritional and phytochemical composition, and explain harvesting and handling practices. These abilities directly align with the Series Learning Outcomes and prepare you for deeper exploration of storage and preservation technologies in the next Series.

Glossary of Terms

- **Bananas**: Fruits of the genus *Musa*, rich in starch that converts to sugars during ripening.
- **Botanical characteristics**: Morphological and physiological traits of fruits and vegetables that influence identification and storage.
- **Citrus fruits**: Fruits of the genus *Citrus*, including oranges, lemons, and grapefruits, known for high vitamin C content.
- **Flavonoids**: Plant phytochemicals with antioxidant properties.
- **Harvesting methods**: Techniques used to collect fruits and vegetables at maturity, either manually or mechanically.
- **Mangoes**: Tropical fruits of the genus *Mangifera*, valued for sweetness and colour.
- **Morphological features**: External structures such as shape, size, colour, and texture.
- **Onions**: Bulb vegetables of the genus *Allium*, containing sulphur compounds responsible for pungency.
- **Phytochemicals**: Naturally occurring plant compounds that provide health benefits beyond basic nutrition.
- **Pigments**: Compounds responsible for colour in fruits and vegetables, such as chlorophyll, anthocyanins, and lycopene.

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- **Post-harvest handling**: Practices applied after harvesting to maintain quality, including sorting, cleaning, packaging, and transport.

Concept Check Questions [Series 2]

Objective questions

1. Which vitamin is most abundant in citrus fruits? (Linked to SLO 2.1)
2. What compounds are responsible for the pungent flavour of onions? (Linked to SLO 2.1)
3. Which pigment gives tomatoes their red colour? (Linked to SLO 2.3)

Short-answer questions

4. Explain why bananas require controlled storage conditions. (Linked to SLO 2.2)
5. Describe one phytochemical and its health benefit. (Linked to SLO 2.3)

Long-answer questions

6. Analyse the importance of morphological and physiological traits in fruit and vegetable technology. (Linked to SLO 2.2)
    - *Basic response*: Morphological traits help in identification and grading, while physiological traits determine storage behaviour.
    - *Value-added response*: These traits also influence consumer acceptance, industrial processing methods, and the design of preservation technologies.
7. Evaluate harvesting methods and post-harvest handling techniques in maintaining produce quality. (Linked to SLO 2.4)
    - *Basic response*: Proper harvesting prevents damage, and post-harvest handling reduces spoilage and ensures food safety.
    - *Value-added response*: These practices also improve marketability, reduce economic losses, and support compliance with international trade standards.

Answers to Pilot Questions [Series 2]

Part 2.1

- Vitamin C.
- Juices and dried slices.
- Sulphur compounds.
- Starch.
- Because they produce high amounts of ethylene and ripen quickly.

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Part 2.2

- External structures such as shape, size, and colour.
- Round shape and thick peel.
- Internal biological processes like respiration and ethylene production.
- Bananas.
- Because they have low respiration rates.

Part 2.3

- Essential nutrients such as carbohydrates, proteins, vitamins, and minerals.
- Potassium.
- Flavonoids, which act as antioxidants.
- Lycopene.
- They provide health benefits beyond basic nutrition.

Part 2.4

- Techniques used to collect produce at maturity.
- Hand-picking.
- Onions.
- Drying onions to reduce moisture and extend shelf life.
- To slow down ripening.

References and Attributions [Series 2]

- Suggested OER sources for diagrams and tables:
    - “citrus fruits OER image”
    - “mango fruit juice OER image”
    - “onion bulb diagram OER”
    - “banana fruit chips OER image”
    - “morphological features fruits vegetables OER image”
    - “physiological traits fruits vegetables OER diagram”
    - “nutritional composition fruits vegetables OER table”
    - “pigments phytochemicals fruits vegetables OER diagram”

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    - “citrus fruit harvesting hand picking OER image”
    - “post harvest handling fruits vegetables OER diagram”
- AI prompt suggestions used for illustrations:
    - Photograph of assorted citrus fruits including oranges, lemons, and grapefruits.
    - Photograph of ripe mangoes and mango juice.
    - Diagram of onion bulb structure highlighting sulphur compounds.
    - Photograph of ripe bananas and banana chips.
    - Photograph showing citrus, mango, onion, and banana highlighting external structures.
    - Diagram comparing respiration and ethylene production in bananas and onions.
    - Table showing carbohydrates, proteins, vitamins, and minerals in citrus, mangoes, onions, and bananas.
    - Diagram showing pigments such as chlorophyll, anthocyanins, carotenoids, and lycopene.
    - Photograph of workers hand-picking citrus fruits in an orchard.
    - Diagram showing post-harvest handling steps including sorting, cleaning, packaging, and transportation.

Series 3: Storage, Preservation and Controlled Atmosphere Technology

Series outline

- **3.1 Principles of Storage**
    - [3.1.1 Factors affecting storage life]
    - [3.1.2 Traditional storage methods]
- **3.2 Preservation Techniques**
    - [3.2.1 Physical methods (e.g., refrigeration, freezing, drying)]
    - [3.2.2 Chemical methods (e.g., preservatives, coatings)]

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- [3.2.3 Biological methods (e.g., fermentation)]

- **3.3 Controlled atmosphere technology**
  - [3.3.1 Principles of controlled atmosphere]
  - [3.3.2 Applications in fruits and vegetables]
- **3.4 Packaging and transportation**
  - [3.4.1 Packaging materials and innovations]
  - [3.4.2 Transportation under controlled conditions]

Introduction

After harvesting, fruits and vegetables remain highly perishable, and without proper storage and preservation, they quickly lose quality, nutritional value, and marketability. Imagine freshly picked mangoes left in the open sun: within days they soften, discolour, and become unfit for sale. This scenario illustrates why effective storage and preservation are critical in fruit and vegetable technology. By applying scientific principles and modern techniques, losses can be minimised, and produce can be delivered safely to consumers.

The aim of this Series is to introduce you to the principles of storage, preservation methods, controlled atmosphere technology, and packaging and transportation practices. You will gain the knowledge and skills needed to maintain the quality of fresh produce and extend its shelf life.

We shall commence this Series by examining the principles of storage, including factors affecting storage life and traditional methods. Next, we will explore preservation techniques, covering physical, chemical, and biological approaches. Following that, we will study controlled atmosphere technology, focusing on its principles and applications in fruits and vegetables. Finally, we will wrap up by considering packaging innovations and transportation under controlled conditions, which ensure produce reaches consumers in optimal quality.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** explain the principles of storage and identify factors affecting storage life,
- **SLO 3.2** describe traditional storage methods used for fruits and vegetables,
- **SLO 3.3** demonstrate knowledge of physical preservation techniques such as refrigeration, freezing, and drying,
- **SLO 3.4** explain chemical preservation methods including the use of preservatives and coatings,
- **SLO 3.5** analyse biological preservation methods such as fermentation,

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- **SLO 3.6** define controlled atmosphere technology and evaluate its applications in fruits and vegetables, and
- **SLO 3.7** assess packaging materials and transportation practices under controlled conditions.

3.1 Principles of Storage

3.1.1 Factors affecting storage life

Storage life refers to the period during which fruits and vegetables can be kept without significant loss of quality. Several factors influence this duration. **Temperature** is the most critical, as higher temperatures accelerate respiration and spoilage, while lower temperatures slow down metabolic activity. **Humidity** also plays a role: low humidity causes wilting, whereas excessive humidity encourages microbial growth. Other factors include **mechanical damage**, which increases susceptibility to decay, and **ethylene production**, which accelerates ripening in crops such as bananas.

Fill in the blank: The environmental factor that accelerates respiration and spoilage when too high is _____.

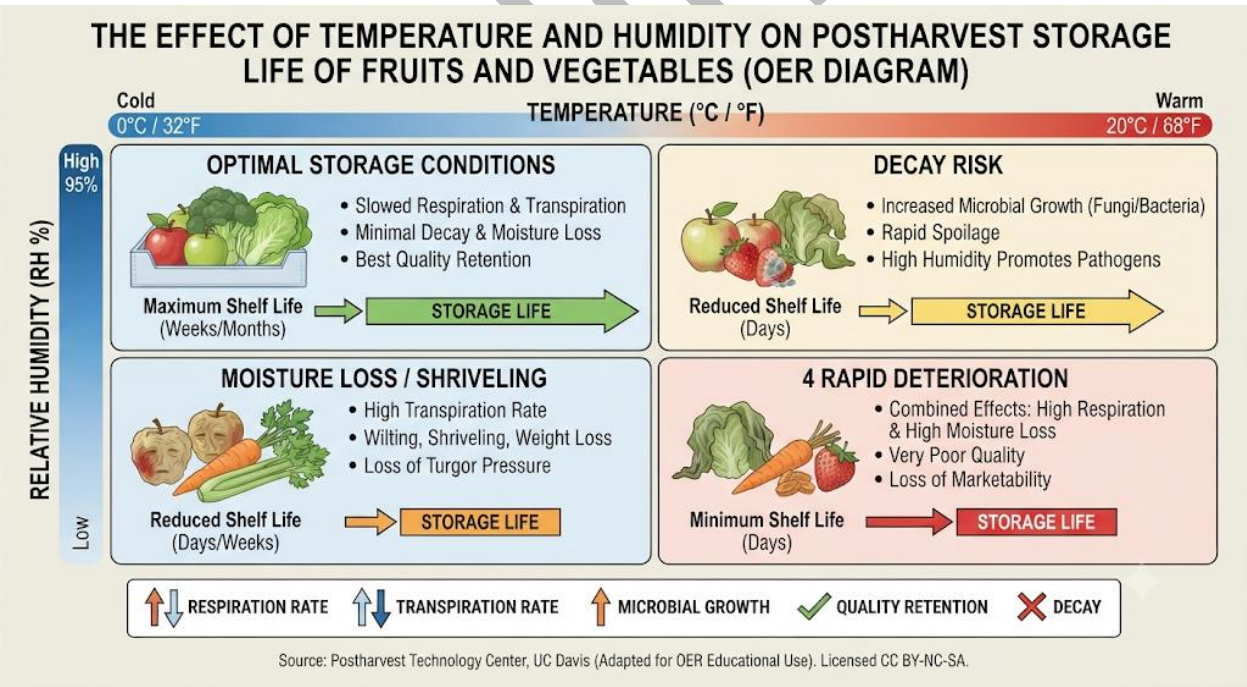

Diagram showing the effect of temperature and humidity on storage life of fruits and vegetables.
Figure 3.1: Factors affecting storage life

3.1.2 Traditional storage methods

Traditional storage methods are practices developed over time to preserve produce without advanced technology. Examples include **pit storage**, where root crops are stored underground to

maintain cool temperatures, and **clay pot storage**, which uses evaporative cooling to keep produce fresh. In rural communities, fruits and vegetables may also be stored in baskets lined with leaves or straw to reduce moisture loss. While these methods are simple and cost-effective, they often provide limited control over environmental conditions compared to modern systems.

Fill in the blank: The traditional storage method that uses underground pits for root crops is called _____.

Image of traditional pit storage for root crops. *Plate 3.1: Traditional pit storage method*

Pilot questions 3.1

1. What is meant by storage life in fruits and vegetables?
2. Which environmental factor accelerates respiration and spoilage when too high?
3. Name one traditional storage method used for root crops.
4. Why is humidity important in storage of fresh produce?
5. What is one limitation of traditional storage methods compared to modern systems?

3.2 Preservation Techniques

3.2.1 Physical methods

Physical preservation methods involve controlling environmental conditions to slow down spoilage. Common techniques include **refrigeration**, which lowers temperature to reduce respiration rates; **freezing**, which halts microbial activity by turning water into ice crystals; and **drying**, which removes moisture to prevent microbial growth. Each method has advantages:

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refrigeration maintains freshness, freezing extends shelf life for months, and drying produces lightweight products suitable for storage and transport.

Fill in the blank: The physical preservation method that removes moisture to prevent microbial growth is _____.

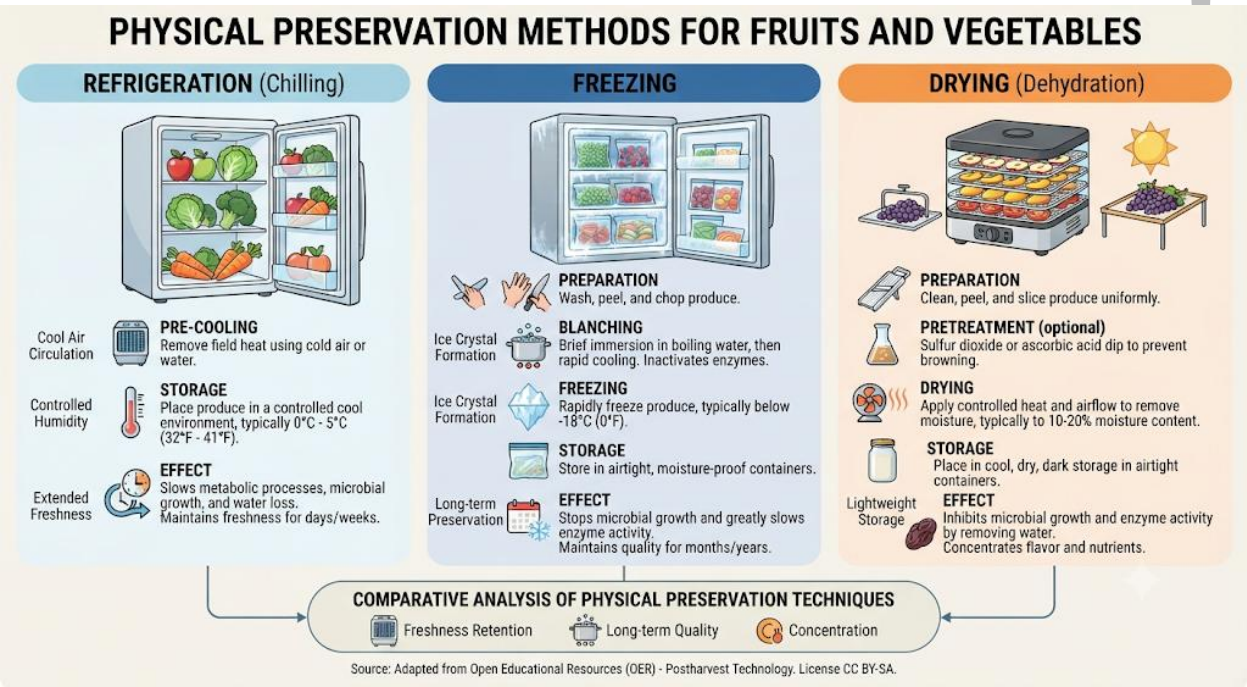

Diagram showing refrigeration, freezing, and drying processes. *Figure 3.2: Physical preservation methods*

3.2.2 Chemical methods

Chemical preservation methods use substances to inhibit microbial growth or delay spoilage. Examples include **preservatives** such as sulphur dioxide in dried fruits, and **coatings** like edible wax applied to apples to reduce moisture loss. These methods are widely used in commercial processing but must comply with food safety regulations to avoid health risks.

Fill in the blank: The chemical commonly used to preserve dried fruits is _____.

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Image of apples with edible wax coating. *Plate 3.2: Apples preserved with edible wax coating*

3.2.3 Biological methods

Biological preservation methods rely on natural processes such as **fermentation**, where microorganisms convert sugars into acids or alcohol. Examples include sauerkraut from cabbage and pickles from cucumbers. Fermentation not only preserves food but also enhances flavour and nutritional value by producing beneficial compounds like probiotics.

Fill in the blank: The biological preservation method that converts sugars into acids or alcohol is called _____.

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Image of sauerkraut and pickled cucumbers. *Plate 3.3: Examples of biological preservation methods*

Pilot questions 3.2

1. What are physical preservation methods and give one example?
2. Which physical method removes moisture to prevent microbial growth?
3. Name one chemical used to preserve dried fruits.
4. What is the purpose of edible wax coatings on apples?
5. What is fermentation and how does it preserve food?

3.3 Controlled Atmosphere Technology

3.3.1 Principles of controlled atmosphere

Controlled atmosphere (CA) technology involves regulating the composition of gases surrounding fruits and vegetables during storage. By adjusting levels of **oxygen**, **carbon dioxide**, and **nitrogen**, metabolic activity can be slowed, thereby extending shelf life. For example, reducing oxygen concentration lowers respiration rates, while increasing carbon dioxide can inhibit microbial growth. This method is particularly useful for perishable crops such as apples, bananas, and leafy greens.

Fill in the blank: Controlled atmosphere storage slows down spoilage by adjusting levels of _____ and carbon dioxide.

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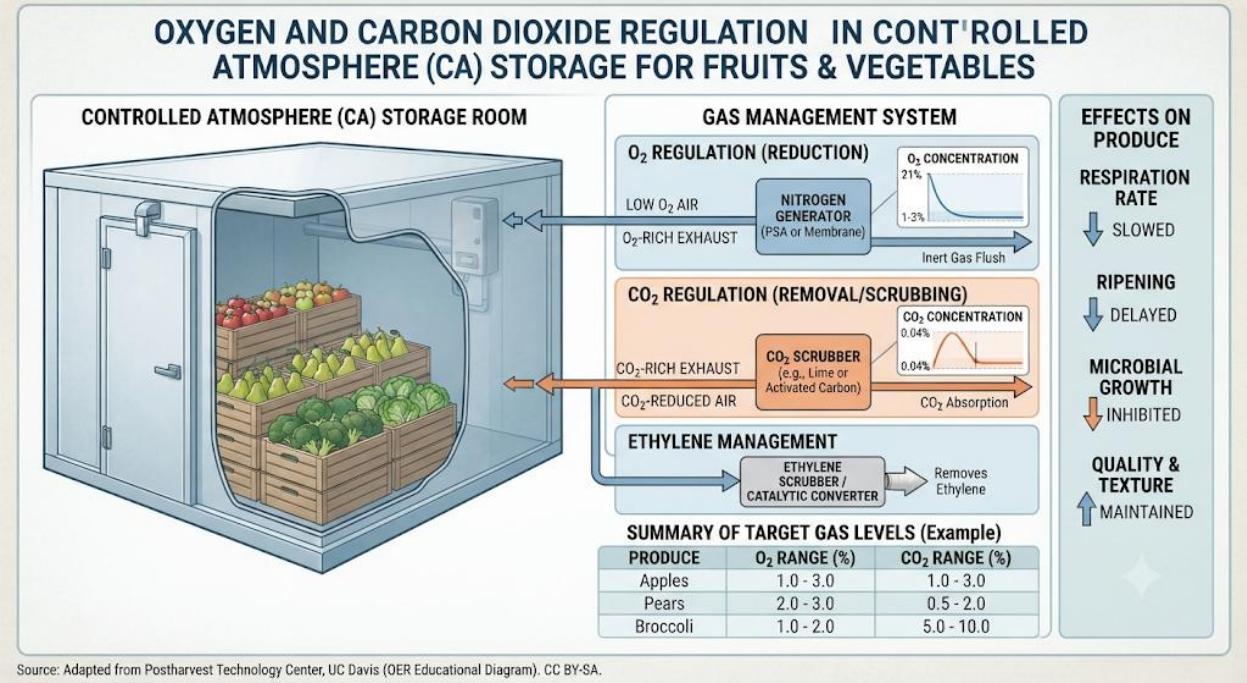

Diagram showing oxygen and carbon dioxide regulation in controlled atmosphere storage. *Figure 3.3: Principles of controlled atmosphere storage*

3.3.2 Applications in fruits and vegetables

Applications of CA technology are widespread in the fruit and vegetable industry. Apples are stored in low-oxygen environments to maintain crispness for months. Bananas benefit from controlled atmosphere during transport, which slows ripening and reduces losses. Leafy greens and berries also retain freshness longer under CA conditions. This technology is essential for international trade, where produce must travel long distances while maintaining quality.

Fill in the blank: Apples are stored in low-oxygen environments under CA technology to maintain _____.

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Image of apples stored in controlled atmosphere facilities. *Plate 3.4: Apples stored under controlled atmosphere conditions*

Pilot questions 3.3

1. What is controlled atmosphere technology?
2. Which gases are regulated in CA storage?
3. Why is reducing oxygen concentration important in CA storage?
4. Name one fruit that benefits from CA technology during transport.
5. How does CA technology support international trade in fruits and vegetables?

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3.4 Packaging and Transportation

3.4.1 Packaging materials and innovations

Packaging materials are essential for protecting fruits and vegetables during storage and distribution. Traditional materials include baskets, wooden crates, and jute bags, while modern innovations involve **plastic films**, **corrugated fibreboard boxes**, and **modified atmosphere packaging (MAP)**. MAP uses specialised films that regulate gas exchange, helping to extend shelf life. Packaging not only prevents mechanical damage but also reduces moisture loss and microbial contamination.

Fill in the blank: The packaging innovation that regulates gas exchange to extend shelf life is called _____.

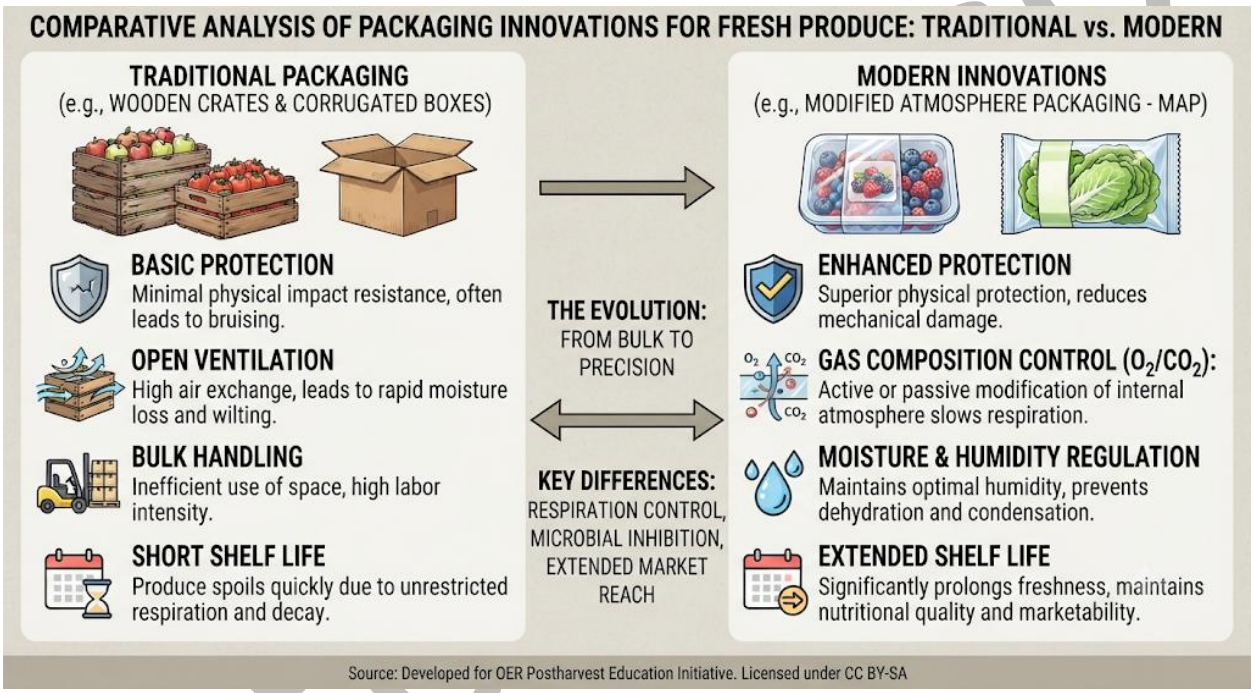

Diagram showing traditional and modern packaging materials for fruits and vegetables. *Figure 3.4: Packaging materials and innovations*

3.4.2 Transportation under controlled conditions

Transportation under controlled conditions ensures that fruits and vegetables maintain quality during long-distance travel. Refrigerated trucks, containers, and ships are commonly used to maintain low temperatures and regulate humidity. Controlled atmosphere containers are particularly useful for bananas, apples, and berries, as they slow down ripening and reduce spoilage. Proper transportation practices are critical for international trade, ensuring produce arrives fresh and safe for consumers.

Fill in the blank: Refrigerated trucks and containers used for transporting fresh produce are commonly called _____ trucks.

Image of refrigerated trucks transporting fresh produce. *Plate 3.5: Transportation of fruits and vegetables under controlled conditions*

Pilot questions 3.4

1. What are packaging materials and why are they important?
2. Name one modern packaging innovation that extends shelf life.
3. What is the purpose of refrigerated trucks in transporting produce?
4. Which fruits benefit from controlled atmosphere containers during transport?
5. How does proper transportation support international trade in fruits and vegetables?

Series Summary

This Series has explored the essential strategies for maintaining the quality of fruits and vegetables after harvest. We began with the principles of storage, examining the factors that affect storage life and traditional methods. We then moved on to preservation techniques, covering physical, chemical, and biological approaches. Following that, we studied controlled atmosphere technology, focusing on its principles and applications in extending shelf life. Finally, we considered packaging innovations and transportation under controlled conditions, which ensure produce reaches consumers safely and in good quality.

By engaging with these topics, you should now be able to explain storage principles, describe preservation methods, evaluate controlled atmosphere technology, and assess packaging and transportation practices. These abilities directly align with the Series Learning Outcomes and provide a strong foundation for advanced study in post-harvest technology.

Glossary of Terms

- **Controlled atmosphere (CA) technology**: Storage method that regulates oxygen, carbon dioxide, and nitrogen levels to slow spoilage.
- **Drying**: Physical preservation method that removes moisture to prevent microbial growth.
- **Fermentation**: Biological preservation method where microorganisms convert sugars into acids or alcohol.
- **Humidity**: Environmental factor influencing wilting and microbial growth during storage.
- **Modified atmosphere packaging (MAP)**: Packaging innovation that regulates gas exchange to extend shelf life.
- **Preservatives**: Chemical substances used to inhibit microbial growth or delay spoilage.
- **Refrigeration**: Physical preservation method that lowers temperature to reduce respiration rates.
- **Storage life**: The period during which fruits and vegetables can be kept without significant loss of quality.
- **Traditional storage methods**: Simple, low-cost practices such as pit storage or clay pot storage.

Concept Check Questions [Series 3]

Objective questions

1. Which environmental factor accelerates respiration and spoilage when too high? (Linked to SLO 3.1)
2. What traditional storage method uses underground pits for root crops? (Linked to SLO 3.2)
3. Which chemical is commonly used to preserve dried fruits? (Linked to SLO 3.4)
4. What biological preservation method converts sugars into acids or alcohol? (Linked to SLO 3.5)
5. Which packaging innovation regulates gas exchange to extend shelf life? (Linked to SLO 3.7)

Short-answer questions

6. Explain why humidity is important in storage of fresh produce. (Linked to SLO 3.1)
7. Describe one advantage of refrigeration as a preservation method. (Linked to SLO 3.3)
8. Why are edible wax coatings applied to apples? (Linked to SLO 3.4)

Long-answer questions

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9. Analyse the importance of physical, chemical, and biological preservation methods in fruit and vegetable technology. (Linked to SLO 3.3–3.5)
    - *Basic response*: Physical methods slow spoilage, chemical methods inhibit microbial growth, and biological methods enhance flavour and nutrition.
    - *Value-added response*: Together, these methods provide a range of options for different crops, balance cost and effectiveness, and support food security by reducing post-harvest losses.
10. Evaluate the role of controlled atmosphere technology and packaging innovations in international trade. (Linked to SLO 3.6–3.7)

- *Basic response*: CA technology slows ripening, and packaging innovations protect produce during transport.
- *Value-added response*: These practices enable long-distance trade, ensure compliance with safety standards, and improve consumer satisfaction by delivering fresh produce across global markets.

Answers to Pilot Questions [Series 3]

Part 3.1

- The period during which produce can be kept without loss of quality.
- Temperature.
- Pit storage.
- It prevents wilting and microbial growth.
- Limited control over environmental conditions.

Part 3.2

- Methods that control environment to slow spoilage, e.g., refrigeration.
- Drying.
- Sulphur dioxide.
- To reduce moisture loss and extend shelf life.
- Conversion of sugars into acids or alcohol by microorganisms.

Part 3.3

- Technology that regulates gases during storage.
- Oxygen and carbon dioxide.

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- It lowers respiration rates.
- Bananas.
- It allows produce to travel long distances while maintaining quality.

Part 3.4

- Materials used to protect produce during storage and transport.
- Modified atmosphere packaging.
- To maintain low temperatures and prevent spoilage.
- Apples, bananas, and berries.
- It ensures produce arrives fresh and safe for consumers.

References and Attributions [Series 3]

- Suggested OER sources for diagrams and tables:
    - “temperature humidity storage life fruits vegetables OER diagram”
    - “pit storage root crops OER image”
    - “physical preservation methods fruits vegetables OER diagram”
    - “apples edible wax coating OER image”
    - “fermentation sauerkraut pickles OER image”
    - “controlled atmosphere storage fruits vegetables OER diagram”
    - “apples controlled atmosphere storage OER image”
    - “packaging materials fruits vegetables OER diagram”
    - “refrigerated trucks fruits vegetables transport OER image”
- AI prompt suggestions used for illustrations:
    - Diagram showing how temperature and humidity affect storage life of fruits and vegetables.
    - Photograph of traditional pit storage for root crops.
    - Diagram showing refrigeration, freezing, and drying processes for fruits and vegetables.
    - Photograph of apples with edible wax coating for preservation.
    - Photograph of sauerkraut and pickled cucumbers showing biological preservation.

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- Diagram showing oxygen and carbon dioxide regulation in controlled atmosphere storage.
- Photograph of apples stored in controlled atmosphere facilities.
- Diagram comparing traditional packaging materials like crates with modern innovations such as modified atmosphere packaging.
- Photograph of refrigerated trucks transporting fresh produce.

Series 4: Canning, Dehydration and Product Processing

Series outline

- **4.1 Principles of canning**
  - [4.1.1 History and importance of canning]
  - [4.1.2 Steps in the canning process]
  - [4.1.3 Safety considerations in canning]
- **4.2 Dehydration techniques**
  - [4.2.1 Sun and solar drying]
  - [4.2.2 Mechanical drying methods]
  - [4.2.3 Freeze-drying]
- **4.3 Processed fruit and vegetable products**
  - [4.3.1 Jams, jellies, and marmalades]
  - [4.3.2 Pickles and chutneys]
  - [4.3.3 Fruit juices and concentrates]
- **4.4 Quality control and packaging**
  - [4.4.1 Standards and regulations]
  - [4.4.2 Packaging materials for processed products]
  - [4.4.3 Shelf life and storage considerations]

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Introduction

Processing technologies transform perishable fruits and vegetables into stable, safe, and marketable products. Without these methods, much of the harvest would spoil before reaching consumers. **Canning** preserves food by sealing it in airtight containers and applying heat to destroy microorganisms. **Dehydration** removes moisture to prevent microbial growth and extend shelf life. Beyond these, a wide range of **processed products**—from jams and jellies to juices and pickles—add value and variety to the food industry.

The aim of this Series is to introduce you to the principles of canning, dehydration techniques, processed fruit and vegetable products, and the role of quality control and packaging. You will gain practical knowledge of how these methods ensure food safety, extend shelf life, and support large-scale distribution.

We shall commence this Series by examining the principles of canning, including its history, process steps, and safety considerations. Next, we will explore dehydration techniques such as sun drying, mechanical drying, and freeze-drying. Following that, we will study processed fruit and vegetable products, including jams, pickles, and juices. Finally, we will wrap up by considering quality control, standards, packaging materials, and shelf life management.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** explain the principles, history, and importance of canning,
- **SLO 4.2** describe the steps in the canning process and identify safety considerations,
- **SLO 4.3** compare dehydration techniques such as sun drying, mechanical drying, and freeze-drying,
- **SLO 4.4** analyse the types of processed fruit and vegetable products and their preparation methods,
- **SLO 4.5** evaluate quality control standards, packaging materials, and shelf life considerations for processed products.

4.1 Principles of Canning

4.1.1 History and importance of canning

Canning is a preservation method that involves sealing food in airtight containers and applying heat to destroy microorganisms. It was first developed in the early 19th century by Nicolas Appert in France, who discovered that heating food in sealed jars prevented spoilage. The process became vital during wars and industrialisation, ensuring safe food supplies over long periods. Today, canning remains important for extending shelf life, reducing waste, and enabling global distribution of fruits and vegetables.

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Fill in the blank: The French inventor credited with developing canning in the early 19th century is _____.

Image of early canning jars and modern canned fruit products. *Plate 4.1: Evolution of canning from jars to modern cans*

4.1.2 Steps in the canning process

The **canning process** involves several steps:

- **Preparation**: Washing, peeling, cutting, or blanching fruits and vegetables.
- **Filling**: Placing produce into cans or jars with syrup, brine, or water.
- **Sealing**: Closing containers to make them airtight.
- **Processing (heating)**: Applying heat to destroy microorganisms and enzymes.
- **Cooling and storage**: Rapid cooling to prevent overcooking, followed by storage under controlled conditions.

Fill in the blank: The step in canning where heat is applied to destroy microorganisms is called _____.

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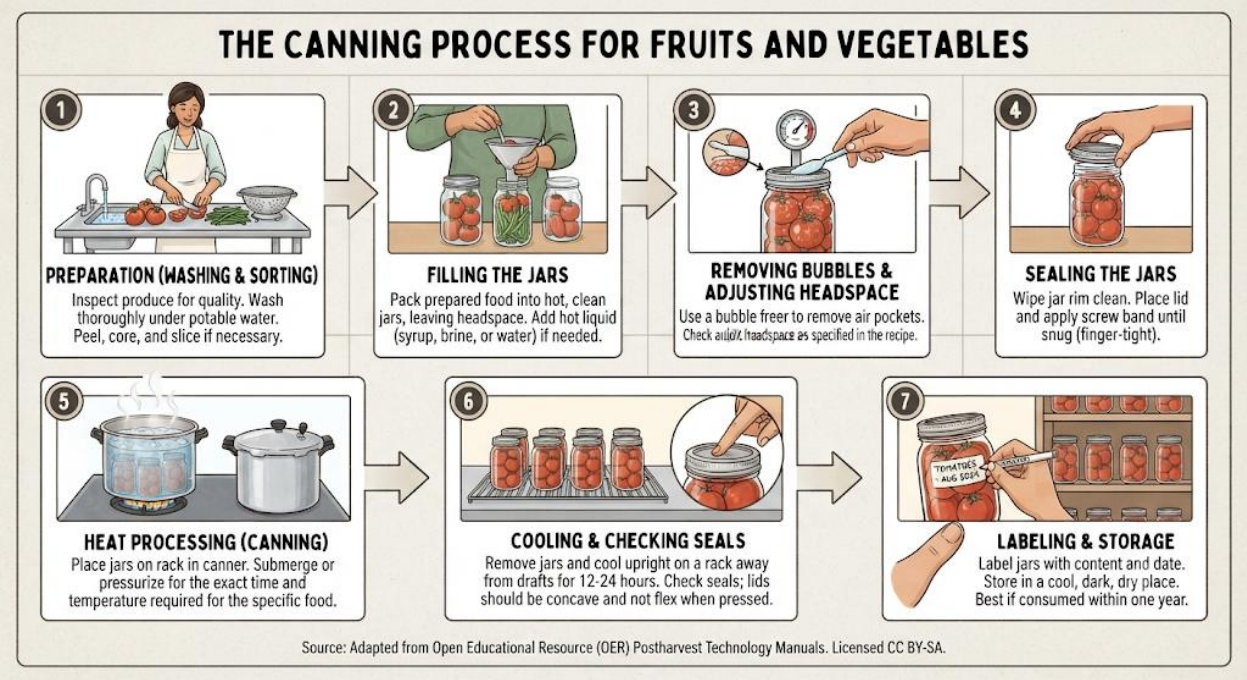

Diagram showing the steps in the canning process. *Figure 4.1: Steps in the canning process*

4.1.3 Safety considerations in canning

Safety in canning is critical because improper processing can lead to **foodborne illnesses**, such as botulism caused by *Clostridium botulinum*. To ensure safety, correct temperatures and processing times must be maintained, especially for low-acid foods like beans and peas. Acidic foods such as tomatoes and citrus fruits are safer to can because acidity inhibits microbial growth. Modern canning also relies on strict quality control standards to guarantee consumer safety.

Fill in the blank: The microorganism that causes botulism in improperly canned foods is _____.

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Image of canned vegetables with safety labels. *Plate 4.2: Safety considerations in canning*

Pilot questions 4.1

1. Who is credited with developing canning in the early 19th century?
2. List the main steps in the canning process.
3. Which step in canning involves applying heat to destroy microorganisms?
4. What microorganism causes botulism in improperly canned foods?
5. Why are acidic foods safer to can compared to low-acid foods?

4.2 Dehydration Techniques

4.2.1 Sun and solar drying

Sun drying is one of the oldest methods of food preservation, where fruits and vegetables are exposed directly to sunlight. It is simple and inexpensive but depends heavily on weather conditions. **Solar drying** improves on this by using solar dryers that concentrate heat and protect produce from dust and insects. Common examples include dried tomatoes, peppers, and mango slices.

Fill in the blank: The traditional dehydration method that relies on direct exposure to sunlight is called _____.

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Image of fruits and vegetables being dried under the sun and in solar dryers. *Plate 4.3: Sun and solar drying methods*

4.2.2 Mechanical drying methods

Mechanical drying uses equipment such as hot-air dryers, tunnel dryers, and drum dryers to remove moisture under controlled conditions. This method is faster, more hygienic, and less dependent on weather compared to sun drying. It is widely used for producing dried onions, banana chips, and apple rings.

Fill in the blank: The drying method that uses equipment like tunnel dryers to remove moisture is called _____ drying.

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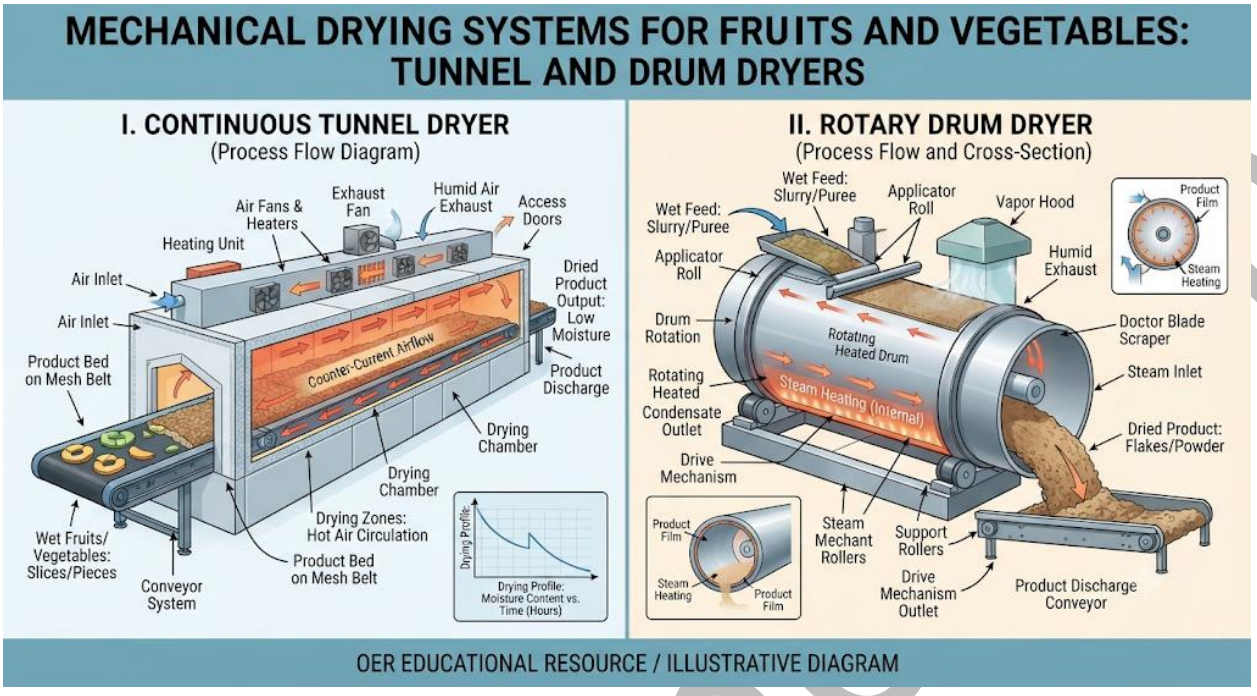

Diagram showing mechanical drying equipment such as tunnel dryers and drum dryers. *Figure 4.2: Mechanical drying methods*

4.2.3 Freeze-drying

Freeze-drying is an advanced dehydration technique where food is first frozen and then moisture is removed by sublimation under vacuum. This method preserves flavour, colour, and nutrients better than other drying methods. Freeze-dried fruits such as strawberries and apples are lightweight, rehydrate quickly, and are popular in instant foods and astronaut diets.

Fill in the blank: The advanced dehydration method that removes moisture by sublimation under vacuum is called _____.

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Image of freeze-dried strawberries and apples. *Plate 4.4: Freeze-dried fruits*

Pilot questions 4.2

1. What is sun drying and what is its limitation?
2. How does solar drying improve on traditional sun drying?
3. Which drying method uses tunnel dryers and drum dryers?
4. What is freeze-drying and why is it considered advanced?
5. Give one example of a fruit commonly freeze-dried.

4.3 Processed Fruit and Vegetable Products

4.3.1 Jams, jellies, and marmalades

Jams, jellies, and marmalades are popular processed fruit products. **Jam** is made by cooking crushed fruit with sugar until it thickens. **Jelly** uses fruit juice instead of pulp, resulting in a clear, firm product. **Marmalade** is a type of jelly made with citrus fruits, often containing peel pieces for added texture. These products preserve fruit flavour and extend shelf life while offering variety to consumers.

Fill in the blank: The processed fruit product made from fruit juice and sugar that results in a clear, firm texture is called _____.

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Image of jam, jelly, and marmalade in jars. *Plate 4.5: Jams, jellies, and marmalades*

4.3.2 Pickles and chutneys

Pickles and chutneys are processed products that enhance flavour and preserve vegetables. **Pickles** are made by immersing vegetables in vinegar or brine, often with spices, to inhibit microbial growth. **Chutneys** are spiced fruit or vegetable pastes cooked with sugar, vinegar, and seasonings. Both products are widely consumed for their tangy taste and long shelf life.

Fill in the blank: Vegetables preserved in vinegar or brine with spices are called _____.

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Image of assorted vegetable pickles and fruit chutneys. *Plate 4.6: Pickles and chutneys*

4.3.3 Fruit juices and concentrates

Fruit juices and concentrates are processed beverages derived from fresh fruits. **Juices** are extracted directly, sometimes pasteurised to ensure safety. **Concentrates** are produced by removing water from juice, making them easier to store and transport. Consumers reconstitute concentrates by adding water before drinking. Examples include orange juice concentrate and mango nectar.

Fill in the blank: The processed fruit product made by removing water from juice for easier storage is called a juice _____.

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Image of fruit juice cartons and concentrates. *Plate 4.7: Fruit juices and concentrates*

Pilot questions 4.3

1. What is the difference between jam and jelly?
2. Which processed fruit product is made with citrus fruits and peel pieces?
3. What are pickles and how are they preserved?
4. What ingredients are commonly used in chutneys?
5. What is the advantage of producing juice concentrates?

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4.4 Quality Control and Packaging

4.4.1 Standards and regulations

Quality control standards ensure that processed fruit and vegetable products are safe, consistent, and acceptable to consumers. Regulatory bodies set guidelines for acidity levels, microbial safety, and nutrient retention. International standards such as **Codex Alimentarius** provide benchmarks for global trade, while national agencies enforce local compliance. Adhering to these standards prevents contamination and builds consumer trust.

Fill in the blank: The international food standards body that provides benchmarks for global trade is called _____.

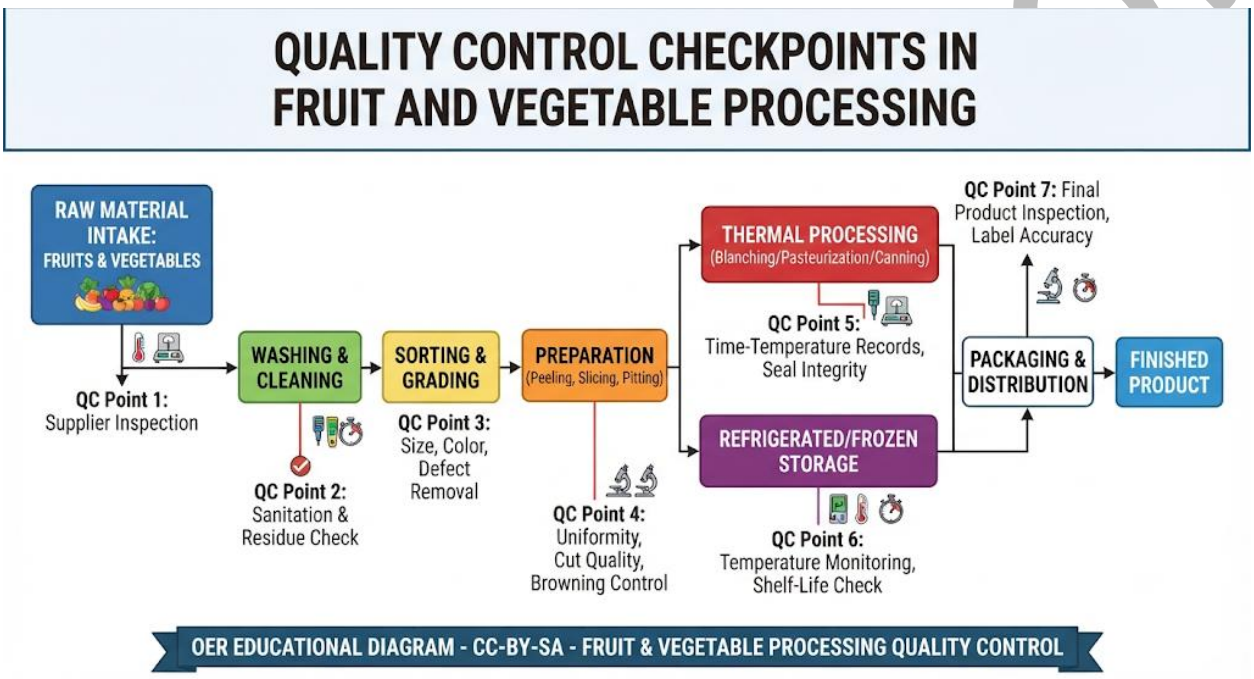

Diagram showing quality control checkpoints in fruit and vegetable processing. *Figure 4.3: Quality control standards in processing*

4.4.2 Packaging materials for processed products

Packaging materials protect processed products from contamination, moisture, and physical damage. Common materials include **glass jars** for jams and pickles, **metal cans** for canned vegetables, and **tetra packs** for juices. Innovations such as vacuum-sealed pouches and laminated films extend shelf life and improve convenience. Packaging also plays a marketing role by attracting consumers with appealing designs.

Fill in the blank: The packaging material commonly used for jams and pickles is _____ jars.

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Image of processed fruit products in glass jars, cans, and tetra packs. *Plate 4.8: Packaging materials for processed products*

4.4.3 Shelf life and storage considerations

Shelf life refers to the period during which processed products remain safe and of acceptable quality. Factors influencing shelf life include acidity, moisture content, packaging, and storage conditions. For example, canned vegetables may last for years if stored properly, while fruit juices in tetra packs have shorter shelf lives. Proper storage—cool, dry, and hygienic environments—ensures products remain safe until consumption.

Fill in the blank: The period during which processed products remain safe and of acceptable quality is called _____.

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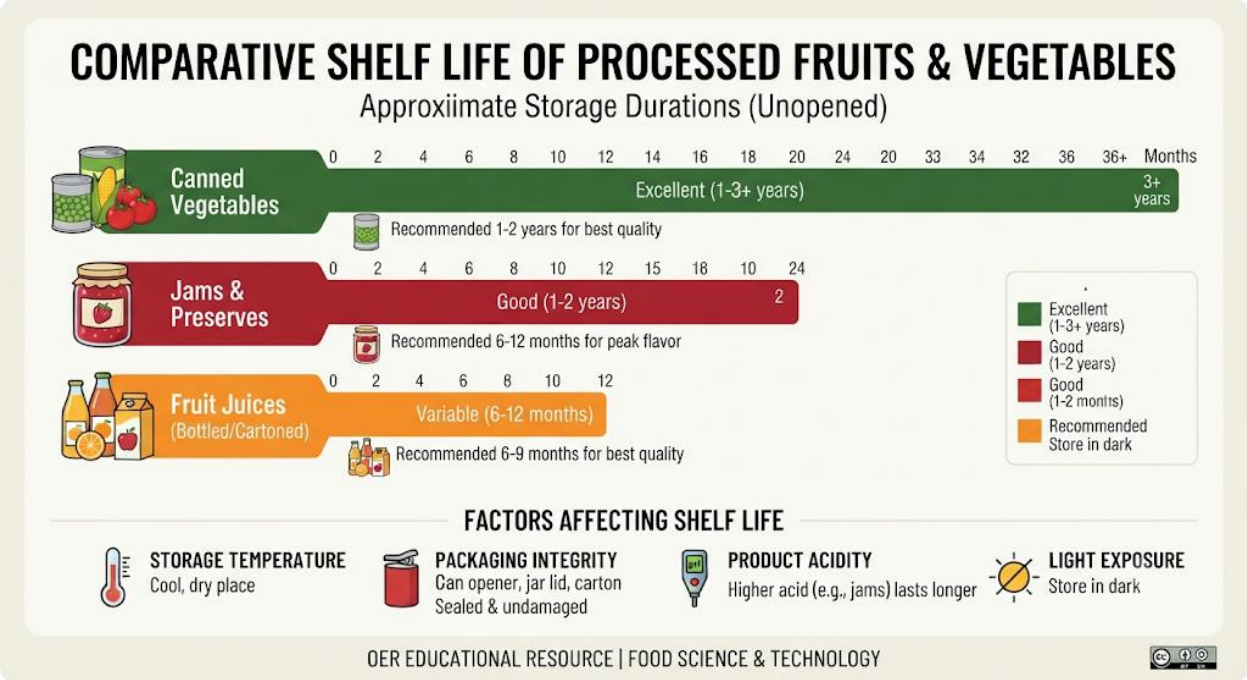

Diagram showing shelf life differences between canned vegetables, jams, and fruit juices. *Figure 4.4: Shelf life and storage considerations*

Pilot questions 4.4

1. What is the role of quality control standards in fruit and vegetable processing?
2. Which international body provides benchmarks for food standards?
3. Name one packaging material commonly used for jams and pickles.
4. What factors influence the shelf life of processed products?
5. Why is proper storage important for processed fruit and vegetable products?

Series Summary

This Series has examined the major processing technologies that transform fruits and vegetables into safe, stable, and marketable products. We began with the principles of canning, covering its history, process steps, and safety considerations. Next, we explored dehydration techniques, including sun drying, mechanical drying, and freeze-drying. We then studied processed fruit and vegetable products such as jams, jellies, marmalades, pickles, chutneys, and juices. Finally, we considered quality control standards, packaging materials, and shelf life management.

By engaging with these topics, you should now be able to explain canning principles, compare dehydration methods, describe processed product types, and evaluate quality control and packaging practices. These abilities align with the Series Learning Outcomes and prepare you for advanced applications in food technology.

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Glossary of Terms

- **Canning**: Preservation method involving sealing food in airtight containers and applying heat to destroy microorganisms.
- **Dehydration**: Process of removing moisture from food to prevent microbial growth.
- **Freeze-drying**: Advanced dehydration method that removes water by sublimation under vacuum.
- **Jam**: Thick fruit product made from crushed fruit and sugar.
- **Jelly**: Clear, firm product made from fruit juice and sugar.
- **Marmalade**: Citrus-based jelly containing peel pieces.
- **Pickles**: Vegetables preserved in vinegar or brine with spices.
- **Chutneys**: Spiced fruit or vegetable pastes cooked with sugar and vinegar.
- **Juice concentrate**: Fruit juice with water removed for easier storage and transport.
- **Codex Alimentarius**: International food standards body providing benchmarks for global trade.
- **Shelf life**: Period during which processed products remain safe and of acceptable quality.

Concept Check Questions [Series 4]

Objective questions

1. Who developed canning in the early 19th century? (Linked to SLO 4.1)
2. Which step in canning involves applying heat to destroy microorganisms? (Linked to SLO 4.2)
3. What drying method uses tunnel dryers and drum dryers? (Linked to SLO 4.3)
4. Which processed fruit product is made with citrus fruits and peel pieces? (Linked to SLO 4.4)
5. What international body provides benchmarks for food standards? (Linked to SLO 4.5)

Short-answer questions

6. Explain why acidic foods are safer to can compared to low-acid foods. (Linked to SLO 4.2)
7. What is freeze-drying and why is it considered advanced? (Linked to SLO 4.3)
8. What is the advantage of producing juice concentrates? (Linked to SLO 4.4)

Long-answer questions

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9. Analyse the importance of canning and dehydration in fruit and vegetable technology. (Linked to SLO 4.1–4.3)
    - *Basic response*: Canning ensures microbial safety, while dehydration reduces moisture to prevent spoilage.
    - *Value-added response*: Together, they extend shelf life, reduce waste, and enable global distribution of diverse products.
10. Evaluate the role of quality control standards and packaging innovations in ensuring consumer safety and marketability. (Linked to SLO 4.5)

- *Basic response*: Standards prevent contamination, and packaging protects products.
- *Value-added response*: These practices also support international trade, enhance consumer trust, and improve product competitiveness.

Answers to Pilot Questions [Series 4]

Part 4.1

- Nicolas Appert.
- Preparation, filling, sealing, heating, cooling, and storage.
- Processing (heating).
- *Clostridium botulinum*.
- Because acidity inhibits microbial growth.

Part 4.2

- Sun drying; limitation: weather dependence.
- Solar drying uses dryers to concentrate heat and protect produce.
- Mechanical drying.
- Freeze-drying removes moisture by sublimation under vacuum.
- Strawberries.

Part 4.3

- Jam uses crushed fruit; jelly uses juice.
- Marmalade.
- Vegetables preserved in vinegar or brine with spices.
- Sugar, vinegar, and seasonings.

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- Easier storage and transport.

Part 4.4

- Ensure safety, consistency, and acceptability.
- Codex Alimentarius.
- Glass jars.
- Acidity, moisture, packaging, and storage conditions.
- To keep products safe and of good quality until consumption.

References and Attributions [Series 4]

- Suggested OER sources for diagrams and tables:
    - “history of canning jars fruits OER image”
    - “canning process steps fruits vegetables OER diagram”
    - “canned vegetables safety labels botulism OER image”
    - “sun drying solar drying fruits vegetables OER image”
    - “mechanical drying tunnel drum dryers fruits vegetables OER diagram”
    - “freeze dried fruits strawberries apples OER image”
    - “jam jelly marmalade fruits OER image”
    - “pickles chutneys fruits vegetables OER image”
    - “fruit juice concentrate packaging OER image”
    - “quality control standards fruits vegetables processing OER diagram”
    - “packaging materials processed fruits vegetables OER image”
    - “shelf life processed fruits vegetables OER diagram”
- AI prompt suggestions used for illustrations:
    - Photograph showing early canning jars and modern canned fruit products.
    - Diagram showing preparation, filling, sealing, heating, and cooling steps in canning process.
    - Photograph of canned vegetables with safety labels highlighting food safety.
    - Photograph of fruits and vegetables dried under sun and in solar dryers.
    - Diagram showing tunnel dryers and drum dryers used for mechanical drying.

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- Photograph of freeze-dried strawberries and apples.
- Photograph of jars containing jam, jelly, and marmalade.
- Photograph of assorted vegetable pickles and fruit chutneys.
- Photograph of fruit juice cartons and concentrates.
- Diagram showing quality control checkpoints in fruit and vegetable processing.
- Photograph of jams in glass jars, canned vegetables, and fruit juices in tetra packs.
- Diagram comparing shelf life of canned vegetables, jams, and fruit juices.

Series 5: Sanitation, Legislation and Plant Operations

Series outline

- **5.1 Sanitation in food processing**
  - [5.1.1 Importance of sanitation]
  - [5.1.2 Sanitation practices and equipment]
  - [5.1.3 Microbial control in processing plants]
- **5.2 Food legislation and standards**
  - [5.2.1 National and international food laws]
  - [5.2.2 Regulatory agencies and compliance]
  - [5.2.3 Labelling and consumer protection]
- **5.3 Plant operations management**
  - [5.3.1 Layout and workflow in processing plants]
  - [5.3.2 Equipment maintenance and safety]
  - [5.3.3 Waste management and sustainability]
- **5.4 Quality assurance in plant operations**
  - [5.4.1 HACCP and GMP principles]
  - [5.4.2 Monitoring and documentation]

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- [5.4.3 Continuous improvement strategies]

Introduction

In fruit and vegetable technology, maintaining **sanitation**, complying with **legislation**, and ensuring efficient **plant operations** are critical for food safety and quality. Poor sanitation can lead to contamination, foodborne illnesses, and consumer distrust. Legislation provides the framework for standards, regulations, and enforcement, ensuring that products meet safety and quality requirements. Plant operations, meanwhile, involve the organisation, workflow, and management of facilities to guarantee efficiency, sustainability, and compliance.

The aim of this Series is to introduce you to sanitation practices in food processing, food legislation and standards, plant operations management, and quality assurance systems. You will gain knowledge of how these elements interact to safeguard consumer health, support industry compliance, and enhance operational efficiency.

We shall commence this Series by examining sanitation in food processing, including its importance, practices, and microbial control. Next, we will explore food legislation and standards, focusing on national and international laws, regulatory agencies, and labelling. Following that, we will study plant operations management, covering layout, equipment safety, and waste management. Finally, we will wrap up by considering quality assurance systems such as HACCP and GMP, monitoring, and continuous improvement strategies.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** explain the importance of sanitation in food processing and describe sanitation practices and equipment,
- **SLO 5.2** identify microbial control measures in processing plants,
- **SLO 5.3** analyse national and international food legislation and standards,
- **SLO 5.4** evaluate the role of regulatory agencies and labelling in consumer protection,
- **SLO 5.5** describe plant operations management including layout, equipment safety, and waste management,
- **SLO 5.6** apply principles of quality assurance such as HACCP and GMP in plant operations, and
- **SLO 5.7** assess monitoring, documentation, and continuous improvement strategies in food processing plants.

5.1 Sanitation in Food Processing

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5.1.1 Importance of sanitation

Sanitation in food processing is the foundation of food safety. It prevents contamination, reduces the risk of foodborne illnesses, and ensures consumer trust. In fruit and vegetable plants, sanitation is especially critical because fresh produce is highly perishable and often consumed raw. Proper sanitation also improves shelf life and reduces waste, making operations more efficient.

Fill in the blank: The foundation of food safety in processing plants is _____.

Image of workers cleaning equipment in a fruit and vegetable processing plant. *Plate 5.1: Importance of sanitation in food processing*

5.1.2 Sanitation practices and equipment

Sanitation practices include **cleaning** (removing dirt and residues) and **disinfection** (destroying microorganisms). Equipment such as **high-pressure washers**, **steam cleaners**, and **sanitising solutions** are commonly used. Floors, walls, and drains must be cleaned regularly, while tools and machinery require scheduled sanitation to prevent cross-contamination.

Fill in the blank: The sanitation practice that destroys microorganisms after cleaning is called _____.

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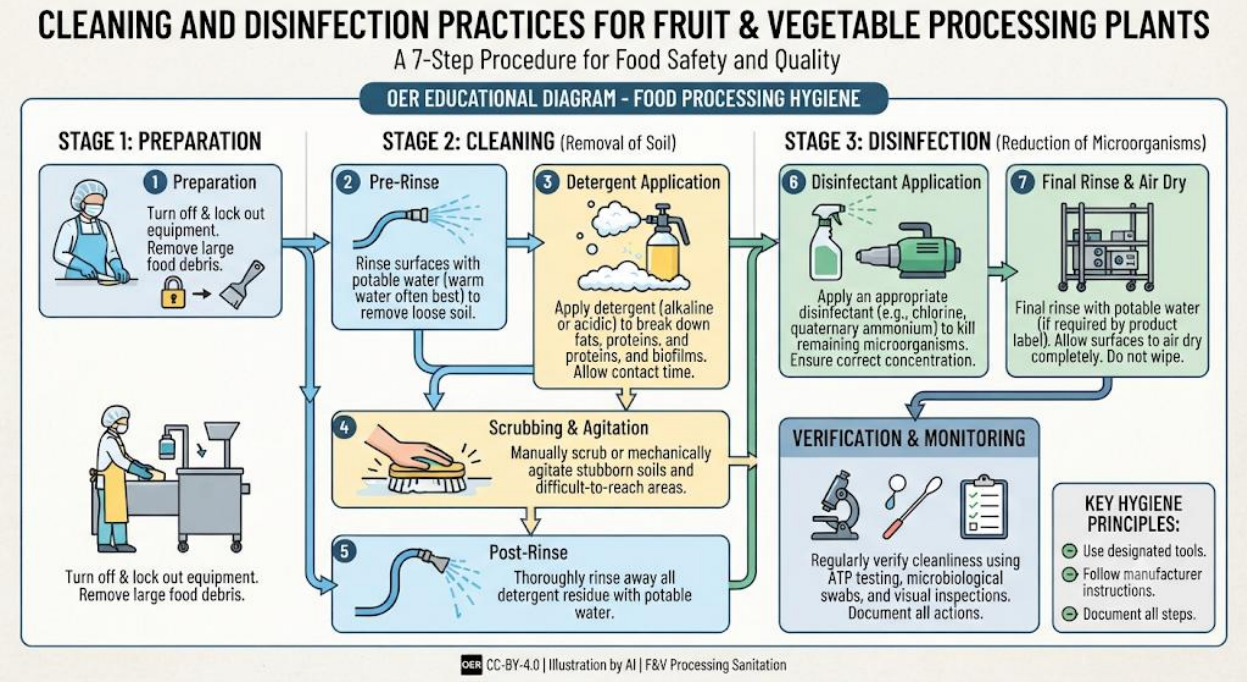

Diagram showing cleaning and disinfection practices in a processing plant. *Figure 5.1: Sanitation practices and equipment*

5.1.3 Microbial control in processing plants

Microbial control involves monitoring and reducing harmful microorganisms in the plant environment. Techniques include **regular microbial testing**, **use of sanitising agents**, and **temperature control** in storage areas. Preventing microbial growth ensures that fruits and vegetables remain safe for consumption and comply with food safety standards.

Fill in the blank: Regular _____ testing is essential for microbial control in processing plants.

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Image of laboratory staff conducting microbial testing in a food plant. *Plate 5.2: Microbial control in processing plants*

Pilot questions 5.1

1. What is the importance of sanitation in food processing?
2. Name two sanitation practices used in processing plants.
3. Which sanitation practice destroys microorganisms after cleaning?
4. What equipment is commonly used for sanitation in food plants?
5. Why is microbial control important in fruit and vegetable processing plants?

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5.2 Food Legislation and Standards

5.2.1 National and international food laws

Food laws establish the legal framework for ensuring safety, quality, and fair trade in food products. National laws vary by country but often cover hygiene, additives, labelling, and permissible contaminants. Internationally, the **Codex Alimentarius Commission** sets harmonised standards that guide global trade and protect consumers. Compliance with these laws ensures that fruit and vegetable products meet both domestic and export requirements.

Fill in the blank: The international body that sets harmonised food standards is the _____ Commission.

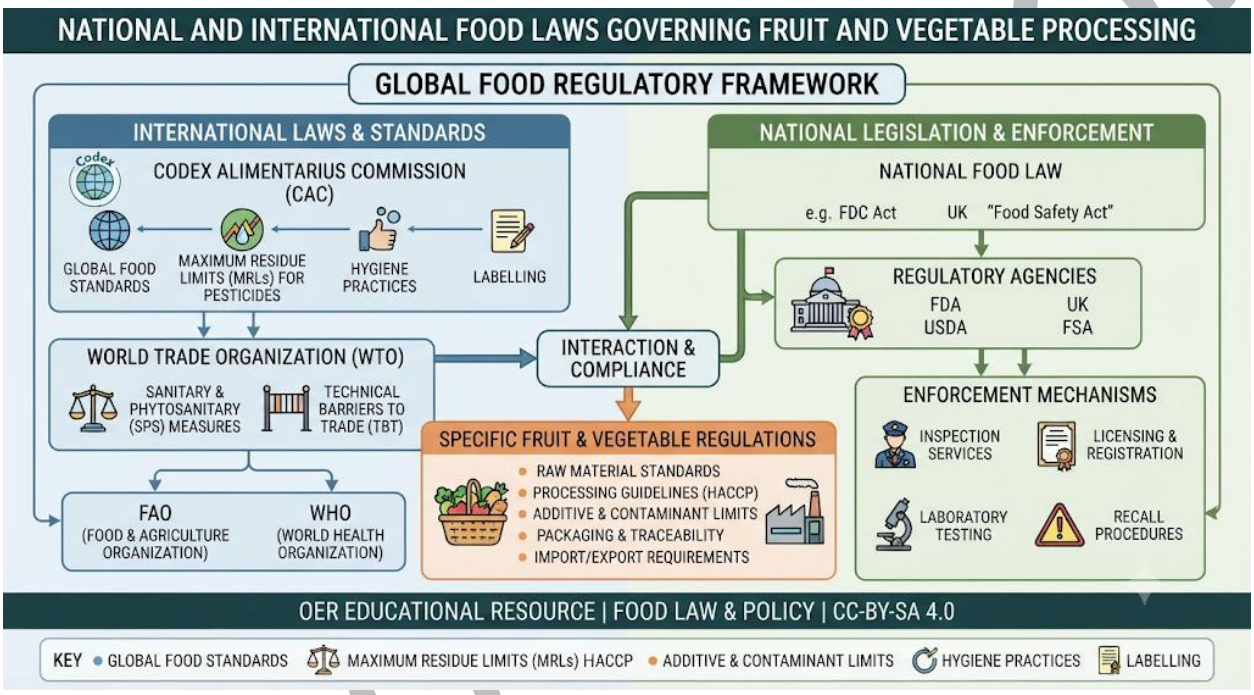

Diagram showing national and international food laws governing fruit and vegetable processing.
Figure 5.2: National and international food laws

5.2.2 Regulatory agencies and compliance

Regulatory agencies enforce food laws and monitor compliance. Examples include the **National Agency for Food and Drug Administration and Control (NAFDAC)** in Nigeria, the **Food and Drug Administration (FDA)** in the United States, and the **European Food Safety Authority (EFSA)** in Europe. These agencies conduct inspections, approve food products, and ensure that manufacturers follow safety standards. Compliance protects consumers and prevents legal penalties for companies.

Fill in the blank: In Nigeria, the regulatory agency responsible for food safety and compliance is _____.

Image of inspectors checking food products in a processing plant. *Plate 5.3: Regulatory agencies ensuring compliance*

5.2.3 Labelling and consumer protection

Labelling provides consumers with essential information about food products, including ingredients, nutritional value, expiry dates, and storage instructions. Proper labelling ensures transparency and protects consumers from fraud or unsafe products. Regulations require that labels be clear, accurate, and not misleading. For processed fruits and vegetables, labelling also indicates additives, preservatives, and country of origin.

Fill in the blank: Labels must be clear, accurate, and not _____.

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Image of packaged fruit products with nutritional labels. *Plate 5.4: Labelling and consumer protection*

Pilot questions 5.2

1. What is the role of food laws in fruit and vegetable processing?
2. Which international body sets harmonised food standards?
3. Name one regulatory agency responsible for food safety in Nigeria.
4. What information must be included on food labels?
5. Why is proper labelling important for consumer protection?

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5.3 Plant Operations Management

5.3.1 Layout and workflow in processing plants

Plant layout refers to the physical arrangement of equipment, workspaces, and storage areas in a processing facility. A well-designed layout ensures smooth workflow, reduces contamination risks, and improves efficiency. For fruit and vegetable plants, layouts often separate raw material handling, processing, packaging, and storage areas to prevent cross-contamination.

Fill in the blank: A well-designed plant layout ensures smooth _____ and reduces contamination risks.

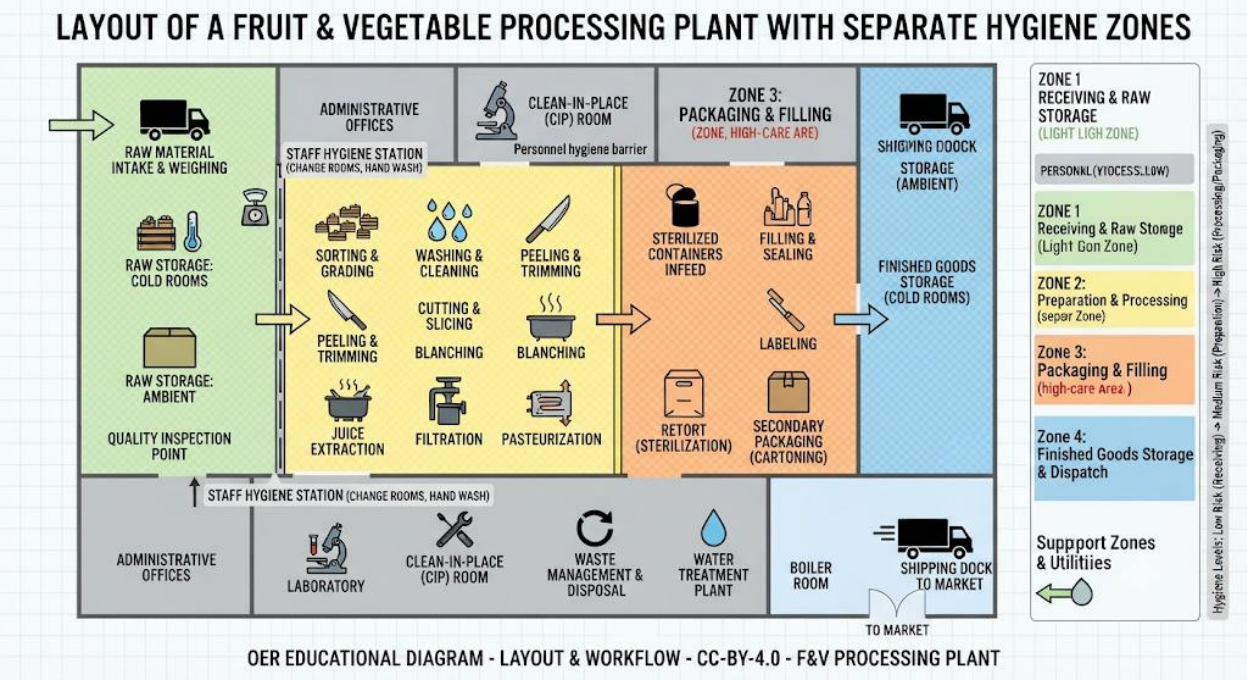

Diagram showing layout of a fruit and vegetable processing plant with separate zones. *Figure 5.3: Layout and workflow in processing plants*

5.3.2 Equipment maintenance and safety

Equipment maintenance is vital to prevent breakdowns and ensure consistent product quality. Regular servicing, cleaning, and calibration of machines reduce downtime and improve safety. Safety measures include protective guards, emergency stop buttons, and staff training. In fruit and vegetable plants, equipment such as washers, cutters, and packaging machines must be maintained to avoid accidents and contamination.

Fill in the blank: Regular servicing, cleaning, and calibration of machines reduce _____ and improve safety.

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Image of technicians maintaining equipment in a food processing plant. *Plate 5.5: Equipment maintenance and safety*

5.3.3 Waste management and sustainability

Waste management in processing plants involves handling by-products, wastewater, and packaging waste. Sustainable practices include recycling, composting organic waste, and treating wastewater before disposal. Efficient waste management reduces environmental impact and improves compliance with regulations. Many modern plants adopt sustainability strategies such as energy-efficient equipment and renewable energy sources.

Fill in the blank: Recycling and composting are examples of _____ practices in waste management.

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Image of composting and recycling practices in a food processing facility. *Plate 5.6: Waste management and sustainability*

Pilot questions 5.3

1. What is the importance of plant layout in fruit and vegetable processing?
2. Name two benefits of regular equipment maintenance.
3. What safety measures are commonly used in food processing equipment?
4. Give two examples of sustainable waste management practices.
5. Why is sustainability important in modern food processing plants?

5.4 Quality Assurance in Plant Operations

5.4.1 HACCP and GMP principles

Hazard Analysis and Critical Control Points (HACCP) is a systematic approach to identifying and controlling food safety hazards. It ensures that risks such as microbial contamination or chemical residues are prevented at critical points in processing. **Good Manufacturing Practices (GMP)** provide guidelines for maintaining hygiene, equipment standards, and staff training. Together, HACCP and GMP form the backbone of quality assurance in fruit and vegetable plants.

Fill in the blank: The systematic approach to identifying and controlling food safety hazards is called _____.

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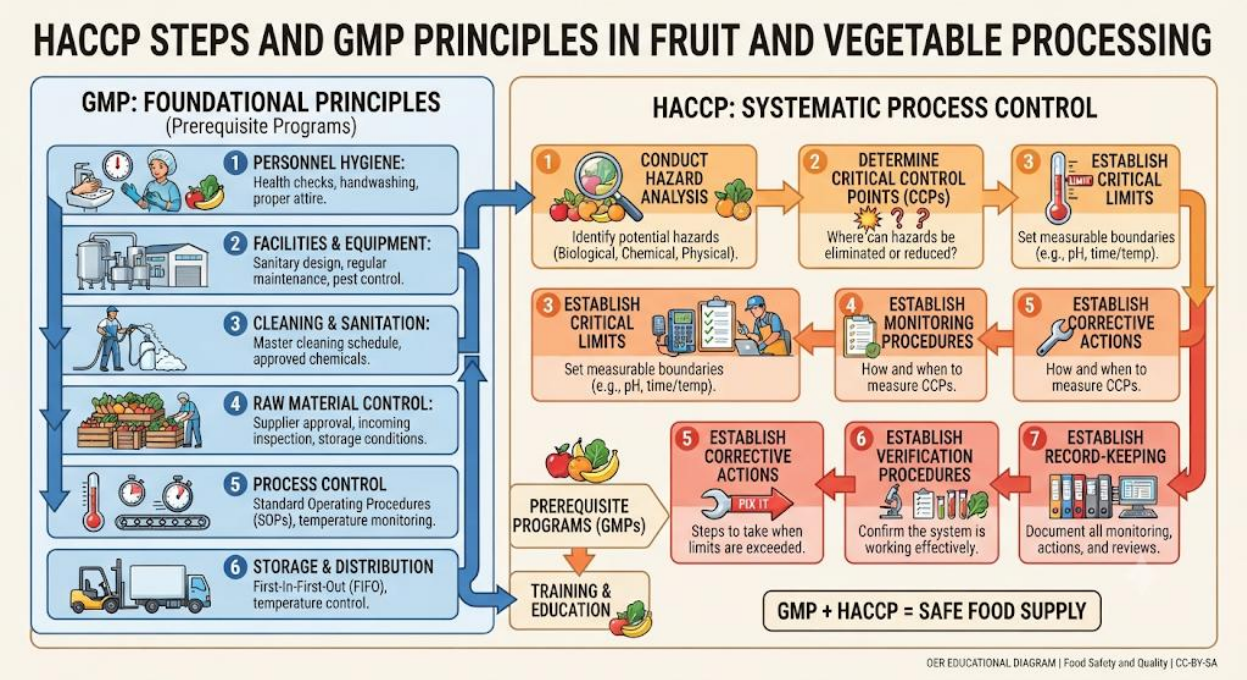

Diagram showing HACCP steps and GMP principles in food processing. *Figure 5.4: HACCP and GMP principles*

5.4.2 Monitoring and documentation

Monitoring involves continuous observation of critical control points, such as temperature in storage or microbial levels in water. **Documentation** ensures that records of inspections, corrective actions, and compliance are maintained. These records are essential for audits, traceability, and consumer confidence. Without proper monitoring and documentation, quality assurance systems cannot function effectively.

Fill in the blank: Continuous observation of critical control points in food processing is called _____.

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Image of staff recording monitoring data in a food processing plant. *Plate 5.7: Monitoring and documentation in plant operations*

5.4.3 Continuous improvement strategies

Continuous improvement in plant operations involves regularly reviewing processes and implementing changes to enhance efficiency and safety. Strategies include staff training, adopting new technologies, and benchmarking against industry standards. Continuous improvement ensures that plants remain competitive, compliant, and responsive to consumer needs.

Fill in the blank: Regularly reviewing processes and implementing changes to enhance efficiency is called _____ improvement.

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Image of a team meeting discussing continuous improvement strategies in a food plant. *Plate 5.8: Continuous improvement strategies in plant operations*

Pilot questions 5.4

1. What is HACCP and why is it important in food processing?
2. What role do GMP principles play in plant operations?
3. Why is monitoring and documentation essential for quality assurance?
4. Give one example of a critical control point in fruit and vegetable processing.
5. What is the purpose of continuous improvement strategies in plant operations?

Series Summary

This Series has explored the essential aspects of **sanitation, legislation, and plant operations** in fruit and vegetable technology. We began with sanitation practices, highlighting their importance, methods, and microbial control. We then examined food legislation and standards, focusing on national and international laws, regulatory agencies, and labelling for consumer protection. Next, we studied plant operations management, including layout, equipment maintenance, and waste management with sustainability practices. Finally, we considered quality assurance systems, covering HACCP, GMP, monitoring, documentation, and continuous improvement strategies.

By engaging with these topics, you should now be able to explain sanitation practices, analyse food legislation, describe plant operations management, and apply quality assurance principles in food processing plants. These abilities align with the Series Learning Outcomes and prepare you for professional practice in food technology.

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Glossary of Terms

- **Sanitation**: Practices that ensure cleanliness and prevent contamination in food plants.
- **Disinfection**: Process of destroying microorganisms after cleaning.
- **Microbial control**: Monitoring and reducing harmful microorganisms in processing environments.
- **Codex Alimentarius**: International body that sets harmonised food standards.
- **Regulatory agency**: Organisation responsible for enforcing food laws and compliance.
- **Labelling**: Providing consumers with product information such as ingredients and expiry dates.
- **Plant layout**: Arrangement of equipment and workspaces to ensure smooth workflow.
- **Waste management**: Handling by-products and waste sustainably in food plants.
- **HACCP**: Hazard Analysis and Critical Control Points, a system for food safety management.
- **GMP**: Good Manufacturing Practices, guidelines for hygiene and operational standards.
- **Continuous improvement**: Regularly reviewing and enhancing processes for efficiency and safety.

Concept Check Questions [Series 5]

Objective questions

1. What is the foundation of food safety in processing plants? (Linked to SLO 5.1)
2. Which sanitation practice destroys microorganisms after cleaning? (Linked to SLO 5.2)
3. What international body sets harmonised food standards? (Linked to SLO 5.3)
4. Which Nigerian agency enforces food safety compliance? (Linked to SLO 5.4)
5. What systematic approach identifies and controls food safety hazards? (Linked to SLO 5.6)

Short-answer questions

6. Why is microbial control important in fruit and vegetable processing plants? (Linked to SLO 5.2)
7. What information must be included on food labels? (Linked to SLO 5.4)
8. Give two examples of sustainable waste management practices. (Linked to SLO 5.5)

Long-answer questions

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9. Analyse the importance of sanitation and legislation in ensuring food safety and consumer protection. (Linked to SLO 5.1–5.4)
    - *Basic response*: Sanitation prevents contamination, while legislation enforces standards.
    - *Value-added response*: Together, they safeguard consumer health, build trust, and enable international trade compliance.
10. Evaluate the role of HACCP, GMP, and continuous improvement strategies in plant operations. (Linked to SLO 5.6–5.7)

- *Basic response*: HACCP and GMP ensure safety, while continuous improvement enhances efficiency.
- *Value-added response*: These systems create a culture of safety, accountability, and innovation, ensuring competitiveness in global markets.

Answers to Pilot Questions [Series 5]

Part 5.1

- Sanitation.
- Cleaning and disinfection.
- Disinfection.
- High-pressure washers, steam cleaners.
- To ensure safety and compliance.

Part 5.2

- To ensure safety, quality, and fair trade.
- Codex Alimentarius Commission.
- NAFDAC.
- Ingredients, nutritional value, expiry date, storage instructions.
- To protect consumers from fraud and unsafe products.

Part 5.3

- Smooth workflow and reduced contamination.
- Reduces downtime and improves safety.
- Protective guards, emergency stop buttons, staff training.
- Recycling and composting.

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- Reduces environmental impact and ensures compliance.

Part 5.4

- HACCP; it identifies and controls hazards.
- GMP ensures hygiene and operational standards.
- Provides traceability and consumer confidence.
- Temperature in storage areas.
- To enhance efficiency, safety, and competitiveness.

References and Attributions [Series 5]

- Suggested OER sources for diagrams and tables:
    - “sanitation food processing fruits vegetables OER image”
    - “cleaning disinfection practices food processing OER diagram”
    - “microbial testing food processing plant OER image”
    - “national international food laws fruits vegetables OER diagram”
    - “food safety inspectors fruits vegetables OER image”
    - “fruit product labelling consumer protection OER image”
    - “plant layout workflow fruits vegetables processing OER diagram”
    - “equipment maintenance safety food processing fruits vegetables OER image”
    - “waste management sustainability food processing fruits vegetables OER image”
    - “HACCP GMP principles fruits vegetables OER diagram”
    - “monitoring documentation food processing fruits vegetables OER image”
    - “continuous improvement strategies food processing fruits vegetables OER image”
- AI prompt suggestions used for illustrations:
    - Photograph of workers cleaning equipment in fruit and vegetable processing plant.
    - Diagram showing cleaning and disinfection practices in fruit and vegetable processing plant.
    - Photograph of laboratory staff conducting microbial testing in food processing plant.
    - Diagram showing national and international food laws governing fruit and vegetable processing.

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- Photograph of inspectors checking food products in fruit and vegetable processing plant.
- Photograph of packaged fruit products with nutritional labels.
- Diagram showing layout of fruit and vegetable processing plant with separate zones.
- Photograph of technicians maintaining equipment in fruit and vegetable processing plant.
- Photograph of composting and recycling practices in food processing facility.
- Diagram showing HACCP steps and GMP principles in fruit and vegetable processing.
- Photograph of staff recording monitoring data in fruit and vegetable processing plant.
- Photograph of team meeting discussing continuous improvement strategies in food processing plant.

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