COURSE GUIDE

CRP 310
HARVESTING, PROCESSING AND STORAGE OF CROPS

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INTRODUCTION

Harvesting, Processing and Storage of Crops is a three credit course for 300Level students of B.Sc. (Crop Production Program). The course consists of 17 units in five modules which deal with Harvesting methods for tropical crops, Fundamentals and principles of crop storage and transportation, Traditional and modern methods of crop processing and storage, Storage and storage life of harvested crops, Design and operation of equipment for storage and preservation. This course guide tells you briefly what the course is all about, and how you can work through these units. It suggests some general guidelines for the amount of time you are likely to spend studying each unit in order to complete it successfully. It also gives you some guidance on your tutor marked assignments.

WHAT YOU WILL LEARN IN THIS COURSE

The main aim of this course "Harvesting, Processing and Storage of Crops" is to introduce the fundamental principles harvesting methods, processing and storage of crops. You would be able to understand the different harvesting methods of tree crops, roots, tubers and grain crops, the traditional and modern methods of crop processing, storage and shelf-life problems in crop products and the ideal environment for crop processing.

COURSE AIMS

The aim of the course is to acquaint you with the basic principles and practices of harvesting, processing and storage of crops.
This would be achieved through:

- Introducing you to the basic principles harvesting, processing and storage.
- Identifying the best practices of harvesting, processing and storage of different tropical crop.
- Creating a better understanding of the principles of crop transportation
- Creating a better understanding of determination of maturity of field crop.
- Developing a clear understanding of the role of an ideal environment for crop storage.
- Introducing you to the various methods of reducing crop deterioration and the use of preservatives in crop storage.
- Introducing you to designing of modern storage structures and equipment for produce storage and preservation

COURSE OBJECTIVES

In order to achieve the course aims, certain overall objectives have been set. In each unit, specific objectives are set. These are usually stated at the beginning of the unit. You should pay attention to the objectives of each unit before starting to go through them. You can always refer back to the unit's objectives to check your progress. You should also look at them after completing a unit. By so doing you can be sure that you have achieved what the unit expects you to acquire. By meeting these objectives, the aims of the course as a whole would have been achieved. These objectives are to;

- Describe the various maturity indexes for some fruits and vegetable
- Explain the importance of maturity indices and their impact on shelf-life and quality.
- Determine maturity stage of fruits and vegetables using subjective and objective maturity.
- Have a clear understanding of what constitute maturity and ripening in crops
- Distinguish physiological maturity from harvest maturity
- Distinguish the three stages in the life span of fruits and vegetables
- Differentiate maturation and repining
- Describe the different harvesting methods for different crops
- Explain the harvesting methods for cereals
- Understand how to harvest vegetables
- Describe the harvesting methods for tree crops
- Explain the harvesting methods for roots and tubers
- Describe the different methods of preserving crop produce
- Explain the latest handling procedures for crop produce
- Describe chemical method of preservation of crop produce
- Preserve fruits by the dehydration
- Preserve fruit by acidification
- Have a clear understanding of the factors that affect quality of produce during transportation
- Explain hygiene in transport system
- Distinguish the factors that govern selection of mode of transport
- Have an understanding of how to handle whole sale and retail outlets
- Describe the methods of processing cereals
- Describe the methods of processing cassava
- Describe the methods of processing yam
- Describe the methods of processing oil fruits
- Describe the methods of processing oil seeds
- Describe traditional food processing in west Africa and Nigeria

- Describe traditional food fermentation
- Explain the traditional method of flour production
- Understand the processing of fruits and vegetables in Nigeria
- Describe traditional boiling of roots and tubers
- Describe the challenges of processing crop produce
- Describe the strategies for enhancing crop processing
- Understand the future post - harvest priorities
- Describe ideal conditions for storage of crop produce
- Explain the principles of controlled atmosphere storage
- Explain the importance of pre-cooling
- Be able to compare different pre-cooling systems
- Describe the processes that could lead to loss of quality during transportation of crop produce and the measures that could be employed in overcoming them
- To successfully transport crop produce
- Explain the importance of proper packaging and the principles involved in packaging.
- Demonstrate competence in selecting the appropriate packaging container and packaging techniques for a produce item and for different target markets.
- Describe the basic requirements and recommendations for the design of storage structures
- Describe on farm storage structures
- Design modern storage structure
- Identify and describe the different kinds of storage structures commonly used in your locality
- Recommend the most appropriate crop produce storage structure considering the environmental factors
- Recommend the most appropriate structure for the storage of cereals, tubers, roots bulbs, vegetables and fruits.

WORKING THROUGH THIS COURSE

To complete this course you are required to read the study units, read other recommended materials. You will be required to answer some questions based on what you have read in the text to reaffirm the key points. At the end of each unit there are some tutor marked assignments (TMA) which you are expected to submit for marking. The TMA forms part of continuous assessments. At the end of the course is a final examination. The course should take you 12 to 13 weeks to complete. You will find listed the component of the course, what you have to do and how to complete. You will find listed the component of the course, what you have to do and how you should allocate your time to each unit in order to complete the course successfully on time.

COURSE MATERIALS

The main components of the course are:

1. Course guide.
2. Study units.
3. Tutor-Marked Assignments.
4. References.

STUDY UNITS

Module 1 Harvesting Methods For Tropical Crops

Unit 1 Maturity Indices of Harvested Crops
Unit 2 Determination of Maturity
Unit 3 Harvesting Methods of Different Tropical Crops

Module 2 Fundamentals and Principles of Crop storage and Transportation

Unit 1 Principles of Crop Storage
Unit 2 Methods of Reducing Crop Deterioration
Unit 3 Use of Preservatives
Unit 4 Principles of Crop Transportation

Module 3 Traditional and Modern methods of Crop Processing and Storage

Unit 1 Principles of Crop Processing
Unit 2 Modern Methods of Crop Processing
Unit 3 Traditional Food Processing Technology in West Africa.
Unit 4 Challenges of Crop Processing.
Unit 5 Modern Methods of Crop Storage.

Module 4 Storage and Storage-life of Harvested Crops

Unit 1 Storage Life of Harvested Crop Materials.
Unit 2 Storage and Shelf Life Problems.
Unit 3 Ideal Environment for Storage.

Module 5 Design and Operation of Equipment for Storage and Preservation

Unit 1 Designing of Modern Storage Structures
Unit 2 Equipment for Produce Storage and Preservation

TUTOR-MARKED ASSIGNMENTS (TMA)

There are marked assignments and self-assessment in each unit. You would have to do the TMA as a revision of each unit. And there are four tutor-marked assignments you are required to do and submit as your assessment for the course. This would help you to have broad view and better understanding of the subject. Your tutorial facilitator would inform you about the particular TMA you are to submit for marking and recording. Make sure your assignment reaches your tutor before the deadline given in the presentation schedule and assignment file. If, for any reason, you cannot complete your work on schedule, contact your tutor before the assignment is due to discuss the possibility of an extension. Extensions will not be granted after the due date unless there are exceptional circumstances. You will be able to complete your assignment questions from the texts contained in this course material and references however, it is desirable to search other references, which will give you a broader view point and a deeper understanding of the subject.

FINAL EXAMINATION AND GRADING

The final examination for the course will be 3 hours duration and consist of six theoretical questions and you are expected to answer four questions. The total marks for the final examination is 70 marks. The examination will consists of questions, which reflect the tutor-marked assignments that you might have previously encountered and other questions within the course covered areas. All areas of the course will be covered by the assessment. You are to use the time between finishing the last unit and sitting the examination to revise the entire course. You might find it useful to review your Tutor-Marked Assignments before the examination. The final examination covers information from all parts of the course.

MAIN COURSE

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MODULE 1 HAVESTINGMETHODS FOR TROPICAL CROPS

Unit 1 Maturity Indices of Harvested Crops

CONTENTS

1.0 INTRODUCTION

The time necessary for crops to successfully complete reproduction is species and environment dependent. Lifecycles can be completed in a few weeks or take several years depending on the plant species. Crop development is divided into phenol-phases that are affected primarily by light and temperature changes, interacting with phyto-hormones. Some species are influenced more by light and others by temperature

2.0 OBJECTIVES

At the end of studying this unit you would able to:

- describe the various maturity indexes for some fruits and vegetable
- explain the importance of maturity indices and their impact on shelf-life and quality
- determine maturity stage of fruits and vegetables using subjective and objective maturity indices.

3.0 Maturity/ Quality indices of crop products

Maturity at harvest is the most important determinant of storage-life and final fruit quality. Immature fruit are highly susceptible to shriveling and mechanical damage, and are of inferior flavor quality when ripe. Overripe fruit are likely to become soft and mealy with insipid flavor soon after harvest. Fruit picked either prematurely or too late, are more susceptible to post-harvest physiological disorders than are fruit picked at the proper stage of maturity.

With a few exceptions all fruits attain optimal eating quality when allowed to ripen on the plant. Some fruits are, however, picked at a mature but unripe stage of development so as to allow them to withstand post-harvest handling conditions when shipped over long-distances. Maturity indices for such fruit are based on a compromise between those indices that would ensure the best eating quality to the consumer and those that provide flexibility in marketing.

Fruit can be divided into two groups: (1) those that are incapable of continuing their ripening process once removed from the plant, and (2) those that can be harvested at the mature stage and allowed to ripen off the plant. Group 1 includes cane berries, cherry, citrus fruits, grape, lychee, pineapple, pomegranate and strawberry. Group 2 on the other hand, includes apple, apricot, avocado, banana, cherimoya, guava, kiwifruit, mango, nectarine, papaya, passion fruit, pear, peach, persimmon, plum, quince and sapodilla
Fruit of the Group 1 category, produce very small quantities of ethylene and do not respond to ethylene treatment except in terms of de-greening (removal of chlorophyll); these should be picked when fully-ripe, if good flavor quality is to be ensured. Fruit of the Group 2 category on the other hand, produce comparably larger quantities of ethylene which is associated with their ripening, and undergo more rapid and uniform ripening upon exposure to ethylene.

Many vegetables, in particular leafy vegetables and immature fruit-vegetables (such as cucumbers, sweet corn, green beans, peas, and okras), attain optimum eating-quality prior to reaching full maturity.

3.1 Maturity indices

The maturity index of a fruit provides an indication of its stage of development or maturation. Maturity indices are based on characteristics that are known to change as the fruit matures. Maturity indices for harvest can be either subjective or objective

3.1.1 Physical indices of maturity

i. Skin Colour

This factor is commonly applied to fruits, since skin colour changes as fruit ripens or matures. Some fruits exhibit no perceptible colour change during maturation, depending on the type of fruit or vegetable. Assessment of harvest maturity by skin colour depends on the judgment of the harvester, but colour charts are available for cultivars, such as apples, tomatoes, peaches, chili peppers, etc.

ii. Optical methods

Light transmission properties can be used to measure the degree of maturity of fruits. These methods are based on the chlorophyll content of the fruit, which is reduced during maturation. The fruit is exposed to a bright light, which is then switched off so that the fruit is in total darkness. Next, a sensor measures the amount of light emitted from the fruit, which is proportional to its chlorophyll content and thus its maturity.

iii. Shape

The shape of fruit can change during maturation and can be used as a characteristic to determine harvest maturity. For instance, a banana becomes more rounded in cross-sections and less angular as it develops on the plant. Mangoes also change shape during maturation. As the mango matures on the tree the relationship between the shoulders of the fruit and the point at which the stalk is attached may change. The shoulders of immature mangoes slope away from the fruit stalk; however, on more mature mangoes the shoulders become level with the point of attachment, and with even more maturity the shoulders may be raised above this point.

iv. Size

Changes in the size of a crop while growing are frequently used to determine the time of harvest. For example, partially mature cobs of *Zea mays saccharata* are marketed as sweet corn, while even less mature and thus smaller cobs are marketed as baby corn. For banana, the width of individual fingers can be used to determine harvest maturity. Usually a finger is placed midway along the bunch and its maximum width is measured with caliper; this is referred to as the caliper grade.

v. Aroma

Most fruits synthesize volatile chemicals as they ripen. Such chemicals give fruit its characteristic odour and can be used to determine whether it is ripe or not. These doors may only be detectable by humans when a fruit is completely ripe, and therefore has limited use in commercial situations.

vi. Fruit opening

Some fruits may develop toxic compounds during ripening, such as ackee tree fruit, which contains toxic levels of hypoglycine. The fruit splits when it is fully mature, revealing black seeds on yellow arils. At this stage, it has been shown to contain minimal amounts of hypoglycine or none at all. This creates a problem in marketing; because the fruit is so mature, it will have a very short post-harvest life. Analysis of hypoglycine 'A' (hyp) in ackee tree fruit revealed that the seed contained appreciable hyp at all stages of maturity, at approximately 1000 ppm, while levels in the membrane mirrored those in the arils. This analysis supports earlier observations that unopened or partially opened ackee fruit should not be consumed, whereas fruit that opens naturally to over 15 mm of lobe separation poses little health hazard, provided the seed and membrane portions are removed.

vii. Leaf changes

Leaf quality often determines when fruits and vegetables should be harvested. In root crops, the condition of the leaves can likewise indicate the condition of the crop below ground. For example, if potatoes are to be stored, then the optimum harvest time is soon after the leaves and stems have died. If harvested earlier, the skins will be less resistant to harvesting and handling damage and more prone to storage diseases.

viii. Abscission

As part of the natural development of a fruit an abscission layer is formed in the pedicel. For example, in cantaloupe melons, harvesting before the abscission layer is fully developed results in inferior flavoured fruit, compared to those left on the vine for the full period.

ix. Firmness

A fruit may change in texture during maturation, especially during ripening when it may become rapidly softer. Excessive loss of moisture may also affect the texture of crops. These textural changes are detected by touch, and the harvester may simply be able to gently squeeze the fruit and judge whether the crop can be harvested. Today sophisticated devices have been developed to measure texture in fruits and vegetables, for example, texture analyzers and pressure testers; they are currently available for fruits and vegetables in various forms. A force is applied to the surface of the fruit, allowing the probe of the penetrometer or texturometer to penetrate the fruit flesh, which then gives a reading on firmness. Hand held pressure testers could give variable results because the basis on which they are used to measure firmness is affected by the angle at which the force is applied. Two commonly used pressure testers to measure the firmness of fruits and vegetables are the Magness-Taylor and UC Fruit Firmness testers. A more elaborate test, but not necessarily more effective, uses instruments like the Instron Universal Testing Machine. It is necessary to specify the instrument and all settings used when reporting test pressure values or attempting to set standards.

x. Juice content

The juice content of many fruits increases as the fruit matures on the tree. To measure the juice content of a fruit, a representative sample of fruit is taken and then the juice extracted in a standard and specified manner. The juice volume is related to the original mass of juice, which is proportional to its maturity.

3.1.2 Chemical Indices of Maturity

i. **Sugars:** In climacteric fruits, carbohydrates accumulate during maturation in the form of starch. As the fruit ripens, starch is broken down into sugar. In non-climacteric fruits, sugar tends to accumulate during maturation. As the fruit ripens starch is broken down to sugars. Measurement of sugars indicate the stage of maturity or ripeness, sugar constitute the major portion of soluble solid of the fruit juice. Measurement of TSS is done on refractometer
ii. **Starch:** Starch content in developing fruit of pear and apple provides harvest maturity.
iii. **Acidity:** In many fruits, the acidity changes during maturation and ripening, and in the case of citrus and other fruits, acidity reduces progressively as the fruit matures on the tree.

3.2 Quality Indices of Fruits

Quality i.e. the degree of excellence or superiority of fresh fruits and their products is combination of attributes, properties or characteristics that give each commodity value in terms of human food. The reletive importance of each quality component depends upon the commodity and its intended use (e.g., fresh or processed) and varies among producers, handlers and consumers. To producers a given commodity must have high yield and good appearance, must be easy to harvestand must withstand long distance shipping to markets. Appearance quality, firmness, and shelf-life are important from the point of view of wholesale and retail marketers. Consumers judge quality of fresh fruits on the basis of appearance including freshness and firmness at the time of initial purchases. subsequent purchases depend upon the consumers satisfaction in terms of flavour (eating) quality of the product. Consumers are also concerned about the nutritional quality of fresh fruits, which are only colourful and flavorful components of our diets, buut also a good source of energy, vitamins, minerals, dietery fibers and many bioactive compounds that enhance human health

Maturity indices are important for deciding when a given commodity should be harvested to provide some marketing flexibilty and ensure the attainment of acceptable eating quality to the consumer. These two goals are not always compatiable. The necessity of shiping fruits long distancehas often resulted in harvesting them at less than ideal maturity. This in turn, has resulted in less than optimum quality to the consumer. Most maturity indices are also factors of quality, but there are many important quality indices which are not used in determining optimum harvesting stage. The flavour quality of fruits cannot be accurately determined by appearance factor alone. Also post harvest quality of fruits based on flavour is generally shorter than their postharvest-life based on appearance (such as colour and absence of defects and decay)

3.3 Maturity standards

Maturity standards have been determined for many fruit, vegetable and floral crops. Harvesting crops at the proper maturity allows handlers to begin their work with the best possible quality produce. Produce harvested too early may lack flavor and may not ripen properly, while produce harvested too late may be fibrous or overripe. Pickers can be trained in methods of identifying produce that is ready for harvest. The following table (table 3.2.1) provides some examples of maturity indices.

Table 3.2.1: Examples of Maturity indices of some fruits

Index	**Examples**
Elapsed days from full bloom to harvest	Apples, pears
Mean heat units during development	Peas, apples, sweet corn
Development of abscission layer	Some melons, apples
Surface morphology and structure	Cuticle formation on grapes, tomatoes Netting of some melons Gloss of some fruits (development of wax)
Size	All fruits and many vegetables
Specific gravity	Cherries, watermelons, potatoes
Shape	Angularity of banana fingers Full cheeks of mangos Compactness of broccoli and cauliflower
Solidity	Lettuce, cabbage, Brussels sprouts
Textural properties	
Firmness	Apples, pears, stone fruits
Tenderness	Peas
Color, external	All fruits and most vegetables
Internal color and structure	Formation of jelly-like material in tomato fruits

	Flesh color of some fruits
Compositional factors	
Starch content	Apples, pears
Sugar content	Apples, pears, stone fruits, grapes
Acid content, sugar/acid ratio	Pomegranates, citrus, papaya, melons, kiwifruit
Juice content	Citrus fruits
Oil content	Avocados
Astringency (tannin content)	Persimmons, dates
Internal ethylene concentration	Apples, pears

Source: Kader, A. A. (1983)

Vegetables are harvested over a wide range of maturities, depending upon the part of the plant used as food.
The following table (table 3.2.2) provides some examples of maturity indices of vegetable crops.

Table 3.2.2 Examples of Maturity indices of vegetable crops

Crop		**Index**
Root, bulb and tuber crops		
Radish and carrot		Large enough and crispy
Potato, onion, and garlic		Tops beginning to dry out and topple down
Yam bean and ginger		Large enough (over-mature if tough and fibrous)
Green onion		Leaves at their broadest and longest
Fruit vegetables		
Cowpea, snap bean, potato, sweet pea and winged bean		Well-filled pods that snap readily
Lima bean and pigeon pea		Well-filled pods that are beginning to lose their greenness

Okra		Desirable size reached and the tips of which can be snapped readily
Gourd		Desirable size reached and thumbnail can still penetrate flesh readily (over-mature if thumbnail cannot penetrate flesh readily)
Eggplant, bitter gourd, chayote or slicing cucumber		Desirable size reached but still tender (over-mature if color dulls or changes and seeds are tough)
Sweet corn		Exudes milky sap from kernel if cut
Tomato		Seeds slipping when fruit is cut, or green color turning pink
Sweet pepper		Deep green color turning dull or red
Muskmelon		Easily separated from vine with a slight twist leaving clean cavity
Honeydew melon		Change in fruit color from a slight greenish white to cream; aroma noticeable
Watermelon		Color of lower part turning creamy yellow, dull hollow sound when thumped
Flower vegetables		
Cauliflower		Curd compact (over-mature if flower cluster elongates and become loose)
Broccoli		Bud cluster compact (over-mature if loose)
Leafy vegetables		
Lettuce		Big enough before flowering
Cabbage		Head compact (over-mature if head cracks)
Celery		Big enough before it becomes pithy

Source: Bautista, O.K. and Mabesa, R.C. (eds). (1977)

4.0 CONCLUSION

Maturity in virtually all crops can be divided into two types, physiological maturity which describes that period when sexually induced reproductive growth has ceased, and harvest maturity, where the seed, fruit, or other economically important organ of yield has reached a state of "ripeness" and can be removed from the parent plant for consumption. Maturity at harvest is the most important determinant of storage-life and final fruit quality. Maturity indices are important for deciding when a given commodity should be harvested to provide some marketing flexibilty and ensure the attainment of acceptable eating quality to the consumer.The deteriorative processes which ultimately lead to complete loss of organization and functioning of the plant or its parts are known as senescence

Maturity indexes for most fruits and vegetables could be any or combination of the following such as changes in colour, shape, size, aroma, fruit opening, abscission, leaf changes, firmness, juice content, sugar and acidity

5.0 SUMMARY

Lifecycle duration of all agricultural crops is important to their management for maximum economic yield. For most agronomic crops maturity ratings refer to the time from germination until physiological maturity.

6.0 TUTOR-MARKED ASSIGNMENT (TMA)

1. Describe the physical indices of crop maturity
2. State the chemical indices of crop maturity
3. Give the maturity standards of the following; tomato, okra, cabbage, water melon, carrot, cowpea and sweet corn
4. Give two examples of each of the following:
   - i. Chemicals that delays ripening
   - ii. Chemicals that hasten ripening
   - iii. Climacteric fruits
   - vi. Non- climacteric fruits

4.0 REFERENCES/FURTHER READING

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UNIT 2 MATURITY, RIPENING AND SENESCENCE

CONTENTS

1.0 Introduction

Maturity in virtually all crops can be divided into two types, physiological maturity which describes that period when sexually induced reproductive growth has ceased, and harvest maturity, where the seed, fruit, or other economically important organ of yield has reached a state of “ripeness” and can be removed from the parent plant for consumption. For most agronomic crops maturity ratings refer to the time from germination until physiological maturity. Days to harvest maturity can be different from one season to the next for the same cultivar and is greatly influenced by environmental conditions, especially temperature; relative humidity; and extent of cloud cover after physiological maturity.

2.0Objectives

At the end of this study you would be able to:
- have a clear understanding of what constitute maturity and ripening in crops
- distinguish physiological maturity from harvest maturity
- distinguish the three stages in the life span of fruits and vegetables
- differentiate maturation and repining
- describe senescence

3.0 Understanding Maturity, ripening and senescence

The principles dictating at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence.

Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption.

3.1Types of maturity

i. Physiological maturity –This refers to a particular stage in the development of a plant or plant organ. A crop is physiologically mature when its development is over. A physiologically mature fruit may not necessarily be commercially mature. For example, papayas are harvested for domestic markets at physiological maturity, i.e. when three-quarters of the fruit assumes a yellow-to-green colour.

ii. **Commercial maturity** – refers to the timing of harvest to meet specific market and consumer requirements. A crop is commercially mature when it reaches a developmental stage at which it can be marketed for a specific purpose, e.g. for consumption in the fresh state, or for processing. Papayas, for example, are harvested for export at the mature stage, i.e. when the fruit is firm and easy to handle. On arrival at the destination, the fruit is ripened in ripening rooms. Commercial maturity has little impact on physiological maturity.

3.2Ripening

Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Ripening is defined as the sequence of changes in texture, colour and flavour as a result of physiological and biochemical change that makes the fruit ready for consumption. Artificial ripening is encouraged when climacteric fruits are picked relatively green and subsequently ripened by introducing ethylene or acetylene gas (calcium carbide) e.g. Banana, Mango, Pear and Avocado.

On the basis of the respiratory pattern and ripening behaviour, fruits are classified into two classes such as climacteric fruits and non-climacteric fruits.

Climacteric fruit: These are fruits that attend maximum ripening immediately after harvest high rate respiration and energy at ripening. They are therefore harvested at full maturity stage and ripen after harvest, e.g. Apple, Apricot, Avocado, Banana, Blue berry, Kiwi fruit, Mango, Papaya, Passion fruit, Peach, Peas, Muskmelon, Watermelon and tomato.

Non-climacteric fruits: Harvested at full ripening (90-95%) with complete colour development. In non-climacteric fruits the rate of respiration is less than climacteric fruit. They are difficult to transport and require sophisticated packing material because the fruits are soft and ripened, e.g. Cherry, cucumber, grapes, lemon, pineapple, mandarins etc.

3.2.1Changes occurring during maturation and ripening (physiological and Biochemical)

1) Water: After harvest, during storage and ripening, fruit and vegetable lose water as a result of respiration transpiration and exchange of gas, resulting in water loss. Loss of H_2O depends upon the RH, temperature, anatomical structure and the rate of transpiration and respiration. When the loss is more than 5-10% fruit and vegetable start shrivel and become unusable.
2) Colour: The most common change is the loss of green colour. This change in colour is due to degradation of chlorophyll structure. The degradation however, is due to pH and oxidative systems. The disappearance of chlorophyll is associated with the synthesis of pigments ranges from yellow to red.
3) Carbohydrates (CHO): CHO are important in attaining pleasing fruit flavours through sugar to acid balance, attractive colour and good texture.
4) Organic acids: the nonvolatile organic acids are among the major cellular constituents undergoing changes during the ripening of fruits. As the fruit ripens the acid content is minimize and converted to sugar.
5) Proteins: Proteins are free amino acids, minor constituents of fruit and do not have much role in determining eating quality of the fruit.
6) Flavouring compounds: Aroma plays an important part in the development of optimal eating quality of fruits and vegetables. This is due to the synthesis of many volatile organic compounds during the ripening phase.
7) Enzymes: Many of the chemical and physical processes that occur during ripening of fruits are attributed to enzyme action.

3.2.2 Chemicals used for hastening and delay of ripening of fruit and vegetables
1. **Chemicals that hasten ripening include:**
a) **Ethylene:** Ethylene related compounds –CEPA-2 chloro ethyl phosphoric acid, CPTA-2,4 chloro phenyl ethyl amine. These compounds are used for pre and postharvest treatments of fruits.
b) **Acetylene and calcium chloride:** Calcium carbide treatment is done to generate acetylene to hasten fruit ripening in banana.
c) **Smoke treatment:** Burning and releasing smoke from leaves, twigs or straw will also hasten ripening in mango.
d) **2,4-D:** 2, 4 dichlorophenoxy acetic acid (2,4-D) is used in ripening of guava while
2, 4, 5-T (2, 4, 5-trichlorophenoxy acetic acid) is used in Sapota.

2**. Chemicals used to delay ripening of fruit and vegetables**
a) Cytokinines and Kinetics: Delays chlorophyll degradation and senescence of leafy vegetable.
b) Gibberellins: Post harvest treatments with GA3 retard ripening of tomato and bananas GA_3 lowers respiratory rate, retards in climacteric fruits and delays the process of colour changes.
c) Growth retardants:

i) **MH** – Prevents sprouting of onion bulbs and potato tubers. Also delays ripening of mango.
ii) **Alar**: Reduces fruit firmness, fruit colour development and early maturation .It is applied before harvest. In lettuce it reduces senescence.
iii) **CCC** (Cycocel)-2 chloroethyl – trimethyl ammonium chloride) is used in delaying senescence of vegetables.
3. **Delaying ripening process by skin coating (waxing):**
Edible waxes are coated on fruits which prevent transpiration losses and minimize respiration rate.
a) Sugar wax along with emulsifier is melted and then boiling water is poured slowly to melted ingredients and an emulsion is prepared.

3.2.3 Factors affecting ripening of fruits and vegetables

- Respiration
- Transpiration / water loss
- Ripening Ethylene production
- Pathological stresses
- Mechanical stress
- Temperature stresses.

Respiration: It is the oxidative break down of more complex substrates normally present in cells such as sugars, starch and organic acids to simpler molecules CO_2 and H_2O.
Transpiration / water loss: Fruit and vegetables contain more than 87-95% water and the presence of moisture inside the tissue is responsible for maintenance of turgidity and succulence. Loss of moisture is direct loss to the traders. Hence, the fruit and vegetable are sold by weight.
Ripening: Ripening is associated with some physical and biochemical processes which may lead to senescence and finally result to dead.
Ethylene: Ethylene is a naturally produced gaseous plant growth regulator that has numerous effects on growth, development and storage life of many fruits, vegetables and ornamentals.
Pathological stresses: Disease play major role. Fruit and vegetable affected with disease spoil early and minimize keeping quality/ shelf life.
Mechanical stress: Mechanical damage also affects fruit and vegetables.
Temperature: Temperature like chilling or freezing maximum temperature also affects the fruits and vegetables quality.

3.3Senescence

Senescence is the last stage, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavour, etc. (senescence ends at the death of the tissue of the fruit). The deteriorative processes which ultimately lead to complete loss of organization and functioning of the plant or its parts are known as Senescence. Senescence occurs due to the deposition of waste material. In some plants the whole plant dies after flowering and producing seeds. This is called **whole plant senescence.** Example-annual plants like rice, wheat, beans, tomato, etc. In many other plants, parts above soil die each year and root system stays alive. This is called **organ senescence.**

Role of hormones in senescence: Basic acid and ethylene promote senescence of leaves but cytokines delays senescence and helps leaves remain green for long period. Water stress caused by a deficiency of water manifests its damage as reductions in photosynthetic activity and increases in leaf senescence

Senescence is important at the organ level with respect to decreases in available photosynthetic area, flowering, and fruiting.

3.4 Determination of maturity

If the stage of maturity at which a fruit or vegetable should be harvested is important for its subsequent quality, storage and marketable life. Determination of maturity can be grouped into physical, chemical, physiological, computation, electronic *etc.* based on the principles used for measuring the various parameters.

3.4.1 Physical method

Skin colour: change of skin colour of many fruits at maturity (Tomato, Papaya, litchi, mango) colour charts are used for apple, tomato, peach *etc.* Instruments are also available for measuring colour of fruits and this is mostly used in harvested fruits.

Shape: the shape of fruit and vegetable can change during maturation. e.g. Banana becomes less angular

Size: Size is frequently used to determine at harvest. It is related to market requirement.

Firmness: As fruits mature and ripen the tissues become soften. The softening can be estimated by the finger feel of commodity (Firmness can be measured by penetrometer).

Specific gravity: It is measured through weight of solids or liquids. As fruits mature their specific gravity increases. This method is rarely practiced.

Aroma: Most fruits synthesis volatile chemicals as they ripen. Based on this we can determine whether fruit is ripe.

3.4.2 Chemical method:

a) Sugars, b) starch, c) acidity

a) Sugar: As the fruit ripens starch is broken down to sugars. Measurement of sugars indicate the stage of maturity or ripeness, sugar constitute the major portion of soluble solid of the fruit juice. Measurement of TSS is done on refractometer.

b) Starch: Starch content in developing fruit of pear and apple provides harvest maturity.

c) Acidity: The acidity of many types of fruits change during maturing and ripening.

In citrus, mango, pineapple and many stage other fruits acidity progressively decrease as the fruit matures on the tree.

3.4.3 Physiological methods

Climacteric fruits, in which there is a distinct rise in respiration during ripening, can be sampled and kept at high temperature and respiration rate is measured. By this way we can predict the number of days will take for ripening stage if left on the tree.

Climacteric fruit: harvested at full maturity stage and ripen after harvest. Maximum respiration starts immediately after harvest. Climacteric fruits have long shelf life of 6-8 days and have no need of sophisticated packing material as fruits are hard, e.g., apple, apricot, avocado, banana, blue berry, kiwi fruit, mango, papaya, passion fruit, peach, peas, muskmelon, watermelon and tomato.

Non-climacteric fruits: Harvested at full ripening (90-95%) complete color development. Rate of respiration is less than climacteric fruit. Difficult to transport need sophisticated packing material because the fruits are soft and ripened. e.g. cherry, cucumber, grapes, lemon, pineapple, mandarins etc.

3.4.4 Other methods of determining maturity

i. Computation method

The time required between flowering and fruit being ready for harvesting may be measured by 'heat units' or degree days in a particular environment.

ii. Electronic and other methods

Electronic colour sorter: used in packing houses to sort-out fruits on the basis of colour, e.g Apple, orange *etc*.

iii. **Costing and vibration test**

The sound of fruit when tapped with the knuckle of the finger changes during maturation and ripening- e.g. watermelon and jackfruit.

1.0 Conclusion

Three stages in the life span of fruits and vegetable could be distinguished as maturation, repining and senescence. Phytohormones play a vital role in plant maturation, beginning with germination and in some cases ending with product consumption. Maturation is closely associated with senescence. With respect to maturation, ethylene is known to stimulate flower opening, ripening, and abscission of leaves and fruit. Vegetables are harvested over a wide range of maturities, depending upon the part of the plant used as food. Produce harvested too early may lack flavor and may not ripen properly, while produce harvested too late may be fibrous or overripe.

5.0 Summary

The principle indicating which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Three stages in the life-span of fruits and vegetables are therefore, referred to as maturation, ripening and senescence. Maturity could be physiological or commercial. A fruit is physiologically mature when its development is over, while commercial maturity refers to the timing of harvest to meet specific market and consumer requirement. Ripening overlaps maturation, rendering the produce edible. Senescence is the last stage of the life span of a crop which is characterized by natural degradation of the crop as in loss of texture, flavour, etc.

6.0 Tutor Marked Assessment

i. Distinguish physiological maturity from harvest maturity

ii. Describe the three stages of maturity in the life span of a plant
iii. Explain the role of hormones in senescence
iv. List four factors affecting the ripening of fruits and vegetables

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UNIT 3: HARVESTING METHODS FOR TROPICAL CROPS

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1.0Introduction

In this unit, you will be learning the different methods of harvesting of some of the tropical crops. Harvesting of crops generally is the task that constitutes the concluding stage of land cultivation. Harvesting includes several steps such as cutting in the case cereal like maize, sorghum millet, gathering of the harvest, delivering for processing transportation of the processed material for storage or sale and storage.

You will need to understand that the primary stage in crop harvesting consists of two steps and these include the removal of the bulk plant material (i.e. picking the fruits and berries, cutting the grains and grasses, digging, the tubers and pulling the flax and subsequent producing.

The harvesting method used depends on the different crop species biological characteristics of the crop, climatic conditions, and technical equipment available.

2.0 Objectives

At the end of this unit, you should be able to:

- Describe the different harvesting methods for different crops
- Explain the harvesting methods for cereals
- Understand how to harvest vegetables
- Describe the harvesting methods for tree crops
- Explain the harvesting methods for roots and tubers

3.0 Harvesting of Tropical Crops

Harvesting is an important component of crop production practices. The overall yield of a particular crop depends to some extent on the efficiency of a particular mode of harvesting (e.g. manual or mechanical). Harvesting is done when a crop has reached physiological maturity or at the point of senescence when the leaves begin to change colour from green to yellow and drop (as in cereal grains and legumes, roots and tubers, bulbs) or the fruits showing signs of ripening). However, if crops are harvested too early, the total yield may be affected due to immaturity. Harvesting at the correct stage of maturity reduces greatly thelevel of spoilage of the crop. Where produce is to be held for any length of time, it is preferable to harvest at a mature but unripe stage.

3.1Harvesting of Cereal Crops

In the case of cereal grains, unripe crop contains a high level of moisture and deteriorate more rapidly than mature ones. If matured grain crops are left on the fields much longer, the grains will be adversely affected due to the alternation between rain and sunshine, on one hand and that of dew at night and hot weather during the day.

Repeated wetting and drying cause certain grains such as long grained variety of rice paddy to crack open and shed their grains on the field. Grain legumes split their pods and the seeds drop on the soil. Insect infestation occurs in the field at this time especially field to storage pests. The timing of the harvest is very important, if maximum yields will be guaranteed with minimum loss. Some matured grains like rice are harvested when they still contain some moisture, but, other types such as maize, sorghum, millet, etc, are allowed to remain on the field to dry out sufficiently before harvesting. This is only possible if the weather remains hot and sunny. All harvested grains should be free from cracks, insects and diseases for them to store well. One important point to note when cultivating any crop especially grains is timing planting. This is important so that the time of maturity will coincide with the approaching dry season. For some grains like rice, the heads are harvested with a sickle and are allowed to dry for a few days outside and are then stacked. Cracking which sometimes occurs may be due to rapid drying out in the field before harvesting. For sorghum and millet, the stems are cut low down, bundled together and stacked in the field. Millet heads are cut about 15cm down the stem and are dried before storage. In some localities, the millet heads are arranged in bundles by tying the stalks together with the heads outside. The bundles are rolled up ready for transport.

Maize is harvested by plucking out the ears from the plaint when they are sufficiently dried on the field.

Grains may look dry at the time of harvest but, they still contain a lot of moisture which must be dried up before storage. For this reason, harvested grains are placed in containers or structures which allow a free flow of air between the grains. This ensures that heat and moisture build up is reduced as the grain respires and at the same time discourages the growth of moulds and infestation by insects which affect the quality of stored grain

3.1.1. Harvesting methods for Rice

i. Manual harvesting

In many countries rice ears are cut by hand. A special knife is frequently used in many other countries. For instance, in the Nigeria, rice is cut stem by stem with a knife, 10 cm below the panicle so as to leave straw in the field in amounts large enough to produce grazing for cattle. Nevertheless such practice is labour intensive. To harvest denser varieties (500 stems/m^2) instead of 100 stems/m^2) a sickle is used mainly on a generally wetter produce. But work times remain high (100 to 200) man-hours per hectare for cutting and stocking.

ii. Mechanized harvesting

The first machines used were simple animal-drawn (horses in Europe, oxen in the tropics) or tractor-driven mowing machines fitted with a cutter bar. The improvements made on this equipment have first resulted in the development of swathes. These drop the crop in a continuous windrow to the side of the machine making it easy to pick up the panicles and manually tie them into bundles. The next step forward has been the reaper that forms unbound sheaves; and finally the reaper/binder which has a tying device to produce sheaves bound with a twine. However the supply, cost and quality of the twine are the main problems associated with the use of such equipment. The output of these machines varies between 4 and 10 hours per hectare, which is slow. However, they may be usefully introduced into tropical rice growing areas, where hand harvesting results in great labour problems. In temperate countries they have been gradually replaced by combine harvesters.

3.1.2. Threshing methods

After being harvested paddy bunches may be stacked on the plot. This in-field storage method results in a pre-drying of the rice ears before threshing, the purpose of which is to separate seeds from panicles.

i. Traditional threshing

The traditional threshing of rice is generally made by hand: bunches of panicles are beaten against a hard element (e.g. a wooden bar, bamboo table or stone) or with a flail. The outputs are 10g to 30kg of grain per man-hour according to the variety of rice and the method applied. Grain losses amount to 1-2%, or up to 4% when threshing is performed excessively late; some un- threshed grains can also be lost around the threshing area.

In many countries in Asia and Africa, the crop is threshed by being trodden underfoot (by humans or animals); the output is 30kg to 50kg of grain per man-hour. The same method, but using a vehicle (tractor or lorry) is also commonly applied. The vehicle is driven in circles over the paddy bunches as these are thrown on to the threshing area (15m to 20m in diameter around the stack). The output is a few hundred kg per hour. This method results in some losses due to the grain being broken or buried in the earth.

ii. Mechanized threshing

From a historical viewpoint, threshing operations were mechanized earlier than harvesting methods, and were studied throughout the 18th century.

Two main types of stationary threshing machines have been developed.

The machines of Western design are known as 'through-flow' threshers because stalks and ears pass through the machine. They consist of a threshing device with pegs, teeth or loops, and (in more complex models) a cleaning-winnowing mechanism based upon shakers, sieves and centrifugal fan. The capacities of the models from European manufacturers or tropical countries (Nigeria, Brazil, India, etc.) range from 500 to 2000kg per hour.

In the 70s, IRRI developed an axial flow thresher which has been widely manufactured at local level. Such is the case in Thailand where several thousands of these units have been put into use. They are generally mounted on lorries and working about 500 hours per year.

More recently, a Dutch company (Votex) has developed a small mobile thresher provided with either one or two threshers. The machine has been widely adopted in many rice growing areas. The simple design and work rates of these machines (about 500kg per hour) seem to meet the requirements of rural communities.

The 'hold-on' thresher of Japanese design is so-called because the bundles are held by a chain conveyor which carries them and presents only the panicles to the threshing cylinder, keeping the straw out. According to the condition of the crop, work rates can range between 300kg and 700kg per hour (Iseki model). The main disadvantage of these machines is their fragility

3.1.3. Combined harvesting and threshing methods

Combine-harvesters, as the name implies, combine the actions of reaping and threshing. Either the 'through-flow' or the 'hold-on' principle of threshing may be employed, but the reaping action is basically the same. The main difference is that combine-harvesters of the Western ('through-flow') type are equipped with a wide cutting bar (4-5m) while the working width of the Japanese ('hold-on') units is small (1m). According to the type of machine used, and specially to their working width, capacities range from 2 to 15 hours per hectare.

Such machines are being increasingly used in some tropical countries. In the Senegal river delta region, private contractors or farmers' organizations have recently acquired combine harvesters, mainly of the Western type (Massey Ferguson, Laverda, etc.). So, almost 40% of the Delta surface area is harvested with a pool of about 50 units. Between 200 and 300 hectares of rice are mechanically harvested. In this region the popularity of combine harvesters is high despite their poor suitability for some small-sized fields.

In Brazil, several manufacturers have adapted machines to rice growing conditions by substituting tracks for wheels; some machines are simple mobile threshers equipped with cutter bars.

In Thailand, local manufacturers have recently transformed the IRRI thresher into a combine harvester so as to reduce the labour requirement. The unit can harvest 5ha per day and seems to have been rapidly adopted.

3.1.4. Strippers

Because of their size, conventional harvesters and combine harvesters prove unsuitable for many rice growing areas with small family farm holdings. In response to this problem, research services, during the last ten years, have developed small-sized machines for harvesting the panicles without cutting the straw. Such machines are known as strippers.

In the United Kingdom, a rotor has been developed which is equipped with special teeth for strip-harvesting spikes or panicles. IRRI recently adopted this technology and has developed a 10 hp self-propelled 'stripper gatherer' with a capacity of about 0.1ha per hour. However, the harvested grain has to be threshed and cleaned in a separate thresher. Since harvesting un-threshed produce results in frequent stoppages for emptying the machine, this constitutes the main drawback to the progress of the prototype.

In France, CIRAD-SAR has designed and developed a machine which strips panicles from the plants and threshes them in only one pass. The stripper has been specially designed for harvesting paddy rice on small plots. The essential component is a wire looped in line with the direction of movement of the machine, which is mounted on a three-wheeled carriage and powered by a 9hp engine and with a 30 cm working width.The stripper capacity is about 1 ha per day.

3.2 Harvesting Methods for Maize

3.2.1 Harvesting methods

i. Manual harvesting

In village farming systems the crop is often harvested by hand and cobs are stored in traditional structures. Quite often, the crop is left standing in the field long after the cobs have matured, so that the cobs may lose moisture and store more safely after harvest.

During this period the crop can suffer infestation by moulds and insects and be attacked by birds and rodents. To reduce such risks, an old practice (called "el doblado") is sometimes applied in South and Central America. This involves hand-bending the ears in the standing crop without removing them from the stalks. It helps mainly to prevent rainwater from entering the cobs, and also limits bird attacks; but, because of the high labour requirements involved, the practice is gradually falling into disuse.

Manual harvesting of maize does not require any specific tool; it simply involves removing the cob from the standing stalk. The work time averages 25 to 30 days per ha. Traditionally, maize cobs are commonly stored in their un-husked form. To improve their drying, it is often recommended to remove the husks from the cobs. Maize husking is usually a manual task carried out by groups of women. Some machine manufacturers (e.g. Bourgoin in France) have developed stationary maize huskers, such as the "Tonga" unit.

ii. Mechanized harvesting

The first mechanized harvester to detach ears of maize from the standing stalks, the 'corn snapper', was built in North America in the middle of the 19th century. This was followed by the development of 'corn pickers', which incorporated a mechanism for removing the husks from the harvested ears. The first animal-drawn maize pickers were replaced by tractor-drawn units (l or 2 rows) and then tractor-mounted units (1 row). Finally came the development of self-propelled units capable of harvesting from up to 4 rows. A specific feature in maize harvesters is the header which leaves the stalks standing as it removes the ears.

The rates of work can vary from 2 hours per hectare with a 3-row self-propelled harvester to 5 hours per hectare with a tractor-drawn or -mounted single row unit. Generally speaking, harvest losses range from 3% to 5%, but they may be up to 10%-15% under adverse conditions. Depending on the situation, a single-row harvester can be employed effectively on up to 20 hectares or more; but the use of a multi-row machine demands several tens of hectares to be economically effective.

Specially designed for harvesting maize as grain, the corn-Sheller was initially a cornhusker in which the husking mechanism was replaced by a threshing one (usually of the axial type). Corn-shelters are self-propelled machines of the 3 to 6-row type with capacities of 1 to 2 hours per hectare. The surface areas harvested during a 180-hour campaign range between 100ha (with a 3-row unit) and 200ha (with a 6-row one).

Another alternative consists of equipping a conventional combine with a number of headers corresponding to the machine horsepower. However, although widely used, such a method requires many adjustments to the threshing and cleaning mechanisms.

3.2.2. Threshing methods

i. Shelling and threshing

Traditional maize shelling is carried out as a manual operation: maize kernels are separated from the cob by pressing on the grains with the thumbs. According to the operator's ability the work rate is about 10kg per hour. Outputs up to 20kg per hour can be achieved with hand-held tools (wooden or slotted metal cylinders). To increase output, small disk Sheller such as those marketed by many manufacturers can be recommended. These are hand-driven or powered machines, which commonly require 2 operators to obtain 150kg to 300kg per hour. Another threshing method, sometimes applied in tropical countries, involves putting cobs in bags and beating them with sticks; outputs achieved prove attractive but bags deteriorate rapidly.

ii. **Motorized threshing**

Nowadays many small maize shellers equipped with a rotating cylinder of the peg or bar type, are available on the market. Their output ranges between 500 and 2000kg per hour, and they may be driven from a tractor power take off or have their own engine; power requirements vary between 5 and 15hp according to the equipment involved.

3.3 Millet and Sorghum Harvesting

3.3.1 Manual harvesting

In Africa, cereals constitute the staple food in the human diet. They are harvested almost exclusively by hand, with a knife after bending the taller stems to reach the spikes. Harvesting and removal from the field takes 10 to 20 days per hectare, according to yields. Harvested ears are stored in traditional granaries while the straw is used as feed for cattle or for other purposes (e.g. thatching).

3.3.2 Gradual mechanization of threshing

Women separate the grain from the ears with a mortar and pestle, as it is needed for consumption or for marketing purpose. Tossing it in the air using gourds or shallow baskets cleans the threshed grain. The traditional method threshing is difficult and slow (10kg per woman-day). Consequently, research has been conducted for some years on how to use mechanical method. The mechanical threshing of sorghum ears does not raise any special problems: conventional grain threshers can be used with some modifications; such as adjustment of the cylinder speed, size of the slots in the cleaning screens, etc. On the other hand, the dense arrangement of spikelet on the rachis and the shape of millet ears (especially pearl millet), make their mechanical threshing excessively difficult.

3.3.3Grain cleaning

Threshing operations leave all kinds of trash mixed with the grain; they comprise both vegetable (e.g. foreign seeds or kernels, chaff, stalk, empty grains, etc.) and mineral materials (e.g. earth, stones, sand, metal particles, etc.), and can adversely affect subsequent storage and processing conditions. The cleaning operation aims at removing as much trash as possible from the threshed grain. The simplest traditional cleaning method is winnowing, which uses the wind to remove light elements from the grain.

3.3.4 Mechanized cleaning

The winnower was widely used in the past for on-farm cleaning of seed in Europe. It was either manually powered or motorized with capacities ranging from a few hundred kilograms to several tonnes per hour.

In Europe, with the use of combine harvesters and the development of centralized gathering, seed cleaners in the big storage centres have progressively replaced cereal winnowers. These machines, also equipped with a system of vibrating sieves, are generally capable of very high outputs (several tens of tonnes per hour).

In developing countries, mechanizing the cleaning operation at village level has rarely been seen as a necessity, because of the lack of quality standards in grain trading. However, because of the current trend towards privatization of marketing networks, the demand for cleaning machines will probably increase. The local manufacture and popularization of simple and easily portable equipment, such as winnowers or screen graders suited to cereal crops, need to be encouraged.

3.2 Harvesting of Tree crops

Tree crops are harvested fresh at a point where full flavor and maturity are at equilibrium. Most fruits are picked when almost ripe and before they drop off the tree. Those intended for long distance transportation or for export are picked when they have reached their full size and maturity but before softening. Immediately after harvest, fruits and vegetables show reduction in weight. The flavor and palatability is also affected. For this reason, fruits need careful handling during harvesting and transport. Tree crops such as citrus fruit is harvested by a mechanical picker by advancing a series of rotating disks into the three where the disk engage the fruit and pull it from the tree. The picker includes a housing having wheels for movement between rows of trees with a drive gearing assembly in the housing powered from a tractor. Two disk assemblies, each comprising a pair of longitudinally space elongated support arms having inside ends supported on the housing, having outside ends supports supporting a shift extending longitudinally between the support arms. The disks are arranged in pairs at longitudinally spaced intervals along the shaft with adjacent disks of each pair having oppositely facing surfaces. The arms can be raised and lowered to force the disk into the tree canopies from top to bottom of the trees.

3.2.1 Methods of Harvesting citrus

Fruit crops such as citrus fruit is harvested by a mechanical picker by advancing a series of rotating disks into the three where the disk engage the fruit and pull it from the tree. The picker includes a housing having wheels for movement between rows of trees with a drive gearing assembly in the housing powered from a tractor. Two disk assemblies, each comprising a pair of longitudinally spaced elongated support arms having inside ends supported on the housing, having outside ends supports supporting a shift extending longitudinally between the support arms. The disks are arranged in pairs at longitudinally spaced intervals along the shaft with adjacent disks of each pair having oppositely facing surfaces. The arms can be raised and lowered to force the disk into the tree canopies from top to bottom of the trees.

3.2.3. Methods of Harvesting Coffee

The ripe cherries are harvested from coffee trees by using one of the following methods:

- Selective picking
- Stripping
- Mechanical harvesting

i. **Selective Picking:** Involves picking by hand only the ripe cherries from the tree and leaving behind unripe beans to be harvested at a later time.

This method is characterized by:

- being slow
- giving high quality of the fruit picked
- providing evenness of the harvest
- relatively high costs

ii. Stripping: Involves collecting the ripe and unripe cherries.

This is a procedure that can be performed by hand or machine, and involves stripping the plant of its fruit and leaves. The main characteristics of this process are:

- greater speed
- damage to plants
- unevenness of the harvest
- lower costs

iii. Mechanical harvesting: Collecting the beans using a harvesting machine.
The method used depends on many factors such as time, cost effectiveness, availability of workers, and length of the harvest and difficulty of harvesting conditions, availability of water.
Coffee cherries are ready for harvest when they bright red, glossy, and firm.

3.2.4Harvesting of banana and plantain

For banana and plantain, bunches are harvested at a stage of development, which is assessed, by the shape and angle of the fruit fingers. Usually while the fruit fingers are immature, they are very angular but get filled out to a rounded or full shape when mature. Bananas are harvested green and ripened artificially by placing them in a pit, surrounded and covered with banana leaves and soil, the ripening process is aided by lighting a fire near or around the hole containing the fruit or by placing the bananas on the hot ashes of a fire previously lit in the hole. The fruit are left to ripen for 5 - 6 days and then removed, peeled and placed in a wooden trough made from a hollowed-out tree trunk. For fruits such as melons, the condition of the stem is used as a basis to determine maturity.

3.3Harvesting of Tuber and Root crops

Roots and tubers are harvested when the leaves begin to wilt and dry. These crops are not removed at once from the field but are harvested as at when needed over a period of time. This is so because they store poorly and can easily deteriorate soon after harvests. Harvesting of roots, and tubers involves careful digging of the soil around the crop to avoid bruising and gently lifting up the root/tubers to present breakage (cutting). In the case of cassava, the stem is cut some 15cm above the soil surface before uprooting the tubers. This enhances it storage changes.
However, root-crops and tubers generally present a number of problems during harvesting. They get damaged because they are heavy and of varying weights, and are poorly distributed in the soil. In the case of yams, the tubers varying widely in shape and size and may be irregularly branched. This characteristic may encourage bruising during harvesting. It is important that roots and tubers are dug and handled carefully to avoid wounding. When storage is desirable, the conditions should be such that they do not rot, sprout respire excessively or loss their food reserves. But at the same time, they must continue to live and undergo all the physiological processes that occur within living material.

4.0 Summary

The task of harvesting generally constitute the last stage of the cultivation and that includes the following steps as gathering, delivering, processing and transporting the processed for storage or sale. Harvesting depends solely on the crop variety/species and its biological characteristics being it grain crops or trees, tubers and root crops. Crop maturity is also a determining factor to be considered before harvesting can commence.

Basically, there are two major means of harvesting and these include traditional method, which are manual using hands while the other is the mechanical method that uses machines.

5.0 Conclusion

Understanding the primary stages in harvesting consist of the removal of the bulk plant material i.e. picking the fruits, cutting of the grains and grasses and digging of the tubers and root crops. In achieving these, the method will either be traditionally which is manual and mechanically that involved the use machines for effectiveness and moderate in the amount lost.

6.0Tutors Marked Assignment (TMA)

- Define harvesting
- List the methods of harvesting
- What are the factors to be considered before harvesting can commence?
- Describe the advantages of manual and mechanical harvesting
- What are the methods employed in harvesting coffee?

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MODULE 2: FUNDAMENTALS AND PRINCIPLES OF CROP STORAGE AND TRANSPORTATION

UNIT 1: Principles of Crop Storage

UNIT 2: Methods of Reducing Crop Deterioration

UNIT 3: Use of Preservatives

UNIT 4: Principles of Crop Transportation.

UNIT 1: PRINCIPLES OF CROP STORAGE

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3.0Conclusion

5.0 Summary

6.0 Tutor Marked Assessment

7.0 References and Further Reading

1.0 Introduction

High temperature and high moisture are the most significant factors affecting grain quality in storage. Each can cause rapid decline in germination, malting quality, baking quality, colour, oil composition, and many other quality characteristics.When dried to moisture contents below the safe moisture level, cereals and pulses can be stored for periods of a year or more under a wide range of temperatures, provided that during storage the moisture level does not rise, and precautions against insects are taken.

Crops producing root or stem tubers, have special requirements with respect to storage, because of the high moisture content of the tubers (60 – 80% when fresh)

Two major factors, that is the moisture content of the product when it comes from the field and the relative humidity of the outside air during the storage period, determine the choice for the best storage.

2.0 Objectives

At the end of this unit you should be able to:

- Describe the different harvesting methods for different crops
- Explain the harvesting methods for cereals
- Understand how to harvest vegetables
- Describe the harvesting methods for tree crops
- Explain the harvesting methods for roots and tubers

3.0 Methods of Crop Storage

Insects and moulds impair the quality of grain directly by their feeding and development, and indirectly through generation of heat and moisture. High temperatures and moistures favour development of insects and moulds. Development of insects is limited by temperatures below 15°C, and by moistures below 9% in cereal grains. Development of moulds is limited by high temperature. High moisture and high temperature are the most significant factors affecting grain quality in storage. Each can cause rapid decline in germination, malting quality, baking quality, colour, oil composition, and many other quality characteristics.

Spraying with insecticides or fumigating minimises insect problems but leaves chemical residues in grain, which break down with time. Presence of residues, and their concentration, affects acceptability of the grain to markets. Some markets prefer grain without residues. Grain buyers will not knowingly accept grain treated at rates higher than those specified on the label, or within the specified withholding period.

3.1Cereals and pulses

3.1.1Conditions for storage

When dried to moisture contents below the safe moisture level, cereals and pulses can be stored for periods of a year or more under a wide range of temperatures, provided that during storage the moisture level does not rise, and precautions against insects are taken; insects may still develop at a relative humidity of approximately 35% and temperatures of around 15°C

Table 3.1.1: Safe moisture content for any particular grain may vary slightly depending on the variety (valid for temperatures up to valid for temperatures up to about 27 °C. Higher temperature

	Product	Safe moisture contents %
Cereals	Maize threshed yellow	13
	Maize threshed white	13.5
	Maize flour	11.5
	Paddy rice	14.0
	Husked brown rice	12.0
	Sorghum	13.5
	Millet	15.0
	Wheat	13.5
	Wheat flour	12.0
Pulses	White and kidney bean broad	15
	Cowpea	*15*
	Lentil, pea	*14*

The safe moisture content for any particular grain may vary slightly depending on the variety. The mentioned safe moisture contents are valid for temperatures up to about 27 °C. Higher temperatures require lower moisture content maxima.

3.1.2Methods of Crop Storage

The following two factors determine the choice for the best storage method:

- the moisture content of the product when it comes from the field
- the relative humidity of the outside air during the storage period

(a) Temporary Storage Methods

Such methods are quite often associated with the drying of the crop, and are primarily intended to serve this purpose. They assume the function of storage only if the grain is kept in place beyond the drying period.

(i)Aerial Storage

Maize cobs, sorghum or millet panicles are sometimes tied in bundles, which are then suspended from tree branches, posts, or tight lines, on or inside the house. This precarious method of storage is not suitable for very small or very large quantities and does not provide protection against the weather (if outside), insects, rodents, or thieves.

(ii)Storage on the ground, or on drying floors

This method can only be provisional since the grain is exposed to all pests, including domestic animals, and the weather. Usually it is resorted to only if the producer is compelled to attend to some other task, or lacks means for transporting the grain to the homestead.

(iii)Open Timber Platforms

A platform consists essentially of a number of relatively straight poles laid horizontally on a series of upright posts. If the platform is constructed inside a building, it may be raised just 35-40 cm above ground level to facilitate cleaning and inspection. Platforms in the open may be raised at least 1 m above ground level. They are usually rectangular in shape, but circular or polygonal platforms are common in some countries.

Grain is stored on platforms in heaps, in woven baskets or in bags. In humid countries fires may be lit under elevated platforms, to dry the produce and deter insects or other pests.

Instead of being horizontal and flat, the platform may be conical in shape, the point at the bottom. Up to 3 m in diameter, such platforms facilitate drying because of their funnel shape: at the top they consist of a frame of horizontal poles which is square, circular or polygonal in shape, against which the timbers which form the cone rest; these timbers meet at the bottom on a wide central supporting post

Platforms with roofs (but no walls), of whatever shape or form, may be regarded as transitional types between temporary and long-term stores. In southern Benin, Togo and Ghana, for example, maize cobs in their sheaths are laid in layers on circular platforms with their tips pointing inwards. The platforms are usually between 2 and 3 m in diameter, but some may be more than 6 m wide, with a maximum height of 2.5 m at the centre and 1.5 m at the periphery.

(b) Long-term Grain Storage Methods

(i)Storage baskets (cribs) made exclusively of plant materials

In humid countries, where grain cannot be dried adequately prior to storage and needs to be kept well ventilated during the storage period, traditional granaries (cribs) are usually constructed entirely out of locally available plant materials: timber, reeds, bamboo, etc. Under prevailing climatic conditions most plant material not fairly quickly, and most cribs have to be replaced every two or three years - although bamboo structures may last up to 15 years, with careful maintenance.

Basically similar to the outdoor type of platform described above, in all its variations, the traditional crib differs in always having a roof and wall(s). It may even be elevated at least one metre above ground level, with a fire maintained underneath to assist drying of the contents and, allegedly, to reduce insect infestation. However, such cribs (especially the larger ones) are more commonly raised only 40 to 50 cm above ground level.

Access to the interior of a crib is gained usually over the wall. This may involve raising the roof, but some cribs have a gap between the top of the wall and the roof to facilitate entry. Relatively few cribs have sealable gaps in the wall or floor for the removal of grain.

(ii)Calabashes, gourds, earthenware pots

These small capacity containers are most commonly used for storing seed and pulse grains, such as cowpeas. Having a small opening, they can be made hermetic, by sealing the walls inside and out with liquid clay and closing the mouth with stiff clay, cow dung, or a wooden (cork?) bung reinforced with cloth. If the grain is dry (less than 12% moisture content) there is usually no problem with this kind of storage.

(iii)Jars

These are large clay receptacles whose shape and capacity vary from place to place. The upper part is narrow and is closed with a flat stone or a clay lid: which is sealed in position with clay or other suitable material. Generally kept in dwellings, they serve equally for storing seeds and legumes. So that they may remain in good serviceable condition, they should not be exposed to the sun and should not be either porous or cracked.

(iv)Solid wall bins

Such grain stores are usually associated with dry climatic conditions, under which it is possible to reduce the moisture content of the harvested grain to a satisfactory level simply by sun-drying it. Solid wall bins are therefore traditional in the Sahel region of Africa, and in southern African countries bordering on the Kalahari Desert.

The base of a solid wall bin may be made of timber (an increasingly scarce resource), earth or stone. Earth is not recommended because it permits termites and rodents to enter. The better base is made of stone.

Mud or clay silos are usually round or cylindrical in shape, depending on the materials used Rectangular-shaped bins of this type are less common, because the uneven pressure of the grain inside causes cracking - especially at the corners. Clay, which is the basic material, varies in composition from one place to another. That most commonly used for such construction work is obtained from termites, because the termites add a secretion which gives it better plasticity. To give it added strength, certain straw materials such as rice straw may be mixed with it. The diversity of materials used explains why the capacities of such silos can vary from 150 kg to 10 tonnes.

In West Africa, when only clay is used, the walls are 15 to 20 cm thick. The shape is then more or less cylindrical and the construction is similar to the walls of a house. However, when the clay is strengthened as described above, the bin is usually rounder in shape and resembles a jar; with walls only 2.5 to 5 cm thick, but very strong, so that it is possible to climb on top to enter the silo for regular withdrawal of grain. Vertical internal walls, joining at the centre on a central column, which serves to support the foot when one enters the silo, often compartment the interior. The walls are rendered as smooth as possible, inside and out in such a way as not to offer refuge for insects and their larvae; fissures are sealed with liquid clay before each loading. Similarly, the angles formed by the internal partition walls and external wall are rounded for the same reasons.

In southern Africa, where the bins are commonly rectangular in plan, internal compartments are usually covered with mud-plastered timber ceilings and are accessed via sealable 'windows'. These face a short corridor leading to the exit, which may be fitted with a standard lockable door.

The roof is usually made of thatched grass, with a generous overhang to protect the mud wall(s) from erosion. Where a side door or a detachable 'cap' is not provided, the roof has to be lifted for access to the bin. Such silos can serve for 30 or even 50 years.

(v)Underground Storage

Practiced in India, Turkey, Sahelian countries and southern Africa, this method of storage is used in dry regions where the water table does not endanger the contents. Conceived for long term storage, pits vary in capacity (100 kg to 200 t). Their traditional form varies from region to region and they are usually cylindrical, spherical or amphoric in shape, but other types are also known. The entrance to the pit may be closed either by heaping earth or sand onto a timber cover, or by a stone sealed with mud

The advantages of this method of storage are:

- few problems with rodents and insects;
- low cost of construction compared to that of above-ground storage of similar capacity;
- ambient temperatures are relatively low and constant;
- hardly visible, and therefore relatively safe from thieves;
- no need for continuous inspection.

The disadvantages are:

- construction and digging are laborious;
- storage conditions adversely affect viability; the stored grains can only be used for consumption;
- the grain can acquire a fermented smell after long storage;
- removal of the grain is laborious and can be dangerous because of the accumulation of carbon dioxide in the pit, if it is not completely full;
- inspection of the grain is difficult;
- risks of penetration by water are not small, and the grain at the top and in contact with the walls is often moldy, even if the rest of the stock is healthy.

3.2Cassava

3.2.1Conditions for storage

Root crops, crops producing root or stem tubers, have special requirements with respect to storage, because of the high moisture content of the tubers (60 – 80% when fresh). On the one hand desiccation should be avoided; on the other hand one has to guard against too much humidity around the tubers, which may cause rotting. Living tubers continue to breathe fairly intensively, and this increases at higher temperatures. When high tuber temperatures are combined with airtight storage, lack of oxygen occurs, which results for example in potatoes with black hearts. As the temperature of the product is higher better ventilation is necessary. During storage chemical changes take place in the tubers, which may influence the firmness and the taste. Tubers have a dormancy of a certain period. After this dormant period they start to sprout. This period varies with the crop and the variety and the temperature of storage of the tubers. Yams can be stored for about 4 months at a normal temperature without sprouting but potatoes already start sprouting a little after 5 weeks at 15 °C. Also rodents often attack the tubers during storage. Without cooling the keeping quality of tubers decreases in the following order: Yam, cocoyam, sweet potato, and cassava. Also for each root crop, varieties are known that keep well and others that do not.

Fresh cassava roots suffer very heavy losses when stored for more than a few days. These losses are not caused by the insect pests but by microbial infection and physiological factors. Post-harvest storage of cassava has been a major problem for production, marketing, utilization and industrialization. However, it is a general belief that fresh cassava roots cannot be stored for more than a few days and so farmers prefer to keep the cassava roots in the ground until they are required. When the cassava roots are allowed to remain in the soil as a means of preserving them, the following problems arise

1.The economic value of the land on which it is cultivated is drastically reduced for as long as the matured cassava roots continue to remain in the soil.

2. Internal discolouration takes place rendering the cassava and cassava products, such as gari unacceptable for human consumption and for livestock feed.

3. Microbial rotting occurs.

4. Rodent and Nematode damage occurs

3.2.2 Storage practices

- Traditionally, the problem of storage has usually been overcome by leaving the roots in the ground until needed
- and once harvested, it is immediately processed into a dry form which gives it a longer storage life
- The roots can be left in the ground for several months after reaching maturity but a disadvantage of this system is that large areas of land are occupied by a crop which is already mature and is thus unavailable for further use. Also the roots become more fibrous and woody and their starch content and palatability declines and in addition, susceptibility to pathogenic losses increases

- One means of storing fresh cassava roots, which has been used since ancient times by the Amerindians of Amazonia, is to bury the harvested roots in pits or trenches, a technique probably derived from the common practice of leaving the cassava un-harvested.
- For a short period cassava roots can be kept fresh by being heaped and watered daily and a coating of paste made from earth or mud to preserve the roots for four to six days

3.3 Yam

3.3.1 Curing

Yam can be cured at temperature of 29 - 32 °C and relative humidity of 90 - 95% for 4 days. Satisfactory healing only occurs around deep wounds such as knife cuts. Bruised tubers (with superficial wounds) do not respond to curing. Cutting off the bruised parts before curing can only preserve such tubers.

3.3.2 Storage

The production of yam, unlike that of cassava, is very seasonal and therefore the tubers have to be stored for several months. The termination of dormancy (when sprouting starts) is the main constraint to long term storage. Removal of the shoots extends the storage life.
Storage conditions for cured tubers: approximately 16 °C and 70%relative humidity. Above 16 °C the tubers can be stored for 3 to 4months. Uncured tubers should be stored at a relatively low humidity Below 12 °C chilling injury occurs.

There are three common methods of storing yam tubers

- Barns
- On platforms
- Underground

1. The barn is the commonest form of yam storage in West Africa. It is erected in an open place and consists essentially of a series of vertically-oriented poles to which the yams are tied with rope
2. In platform storage, the yams are laid horizontally on an elevated platform.
3. Underground storage the tubers are placed together in a large ditch and then covered with soil or dry vegetation

Yam tubers storage

- It is essential that the tubers should be well aerated and well shaded
- Tubers should be inspected frequently so that rotten ones can be removed
- The sprout should be removed from those that begin to sprout

Causes of loss during yam tuber storage

- Rotting
- Tuber respiration
- Tuber sprouting
- Moisture loss from the tubers

Cold storage for yam tubers

- Reduces storage losses due to rotting, sprouting and respiration

Limitations

- High cost of refrigeration
- Yams stored at temperatures below 10^{O}C tend to become brown and unsuitable for human consumption

3.4 Sweet potatoes

3.4.1 Curing

Tubers are cured under temperature of approximately 30 °C, relative humidity, 85 %– 90% for 5 – 7days.The tubers can be left in the field in small heaps that are covered at nightwith straw or jute sacks if the temperature drops below 25 °C.

- Curing after harvesting but before storage: the tubers are subjected to curing, a process which promotes the healing of wounds inflicted during harvesting
- Curing is best done by subjecting the freshly harvested tubers to a temperature of 27-30^{o}C and relative humidity of 85-90% for 4–7 days in a well- ventilated ware house
- Curing can be accomplish by simply leaving the tubers exposed to ambient conditions for a few days before they are packed for storage

- After curing the best condition for the storage of sweet potatoes tubers is temperature of 13-^{1o} and relative humidity of 85-90%. The attainment of such condition requires refrigeration which may be uneconomical or unavailable
- Most farmers in Africa simply store their sweet potatoes under ambient conditions in baskets, in underground pits or in platforms.

3.4.2 Storage

The sweet potato has low storage potential in the tropics. Optimum storage conditions after curing: 13 - 16 °C and high relative humidity(85 % - 90%). Higher temperatures promote sprouting and increase respiration, leading to heat production and dry matter loss. Ventilation during storage is of great importance. The tuber is highly susceptible to physical damage and subsequent deterioration. Red varieties seem to be stored better than white varieties. Processing can lessen storage losses in fresh tubers: peeled tubers are sliced and sun dried to produce chips, which can be stored intact or grounding to flour.
Storage Methods include;

- Clamp storage
- Pit storage whereby, the pits are lined with straw or bamboo and covered with a tight fitting (wooden) cover and a roof for protection from the rain. Only possible in areas of good drainage.
- Hut storage

The cured tubers can be stored by wrapping them in newspaper or packing them in dry sawdust. (The sawdust must be dry in order to minimize re-growth and rotting.) They can also be stored in crates lined with plastic. Holes in the plastic allow for ventilation. During the first week curing is allowed to proceed at ambient temperature (18^{o}C - 31 °C). After curing, excess moisture must be removed to prevent sprouting.

3.5 Irish Potato

3.5.1 Storage condition

Optimum storage of Irish potato is at temperature below 10 °C. Potato is a sensitive crop with respect to oxygen need, damaging and infection by fungi, etc. Potatoes should not be exposed to the sun for too long(maximum 1 hour). They should be stored in the dark in a dry and well ventilated place. Under certain tropical conditions potatoes can be left in the ground for a period beyond the time at which it would normally have been harvested under temperate conditions

Methods of storage

- Storage in clamps or (partially) underground pits. Because the rate of respiration is still very high in the beginning the final layer of sand is sometimes applied to the straw after one week.
- Hut storage

The stores are ventilated during the night when the temperature is lower. The stores may be built partially underground with air ducts under the tubers to utilize cool night air.

- Storage in bulk or preferably in small boxes

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3.6 Oil-containing products

Oil-containing products art consumed directly (groundnuts, soybeans, sesame, coconut) or for the extraction of oil. Often the remaining material (the "press cake") can be used as cattle feed. The value of the oil is determined for a large part by the free fatty acid content. This influences the smell and taste of the oil in a negative way. This is especially important if the oil is used locally. The process that liberates these free fatty acids (lipolysis) goes faster at a higher temperature and humidity. The enzymes that play a role in this process are already present in these products naturally, but are produced in greater quantities when infection by insects and fungi and mechanical injury occurs. Apart from influencing taste and appearance of the dried products as well as the oil to be pressed from it, fungi can also form toxic substances like aflatoxin in groundnuts. Fungal growth on oil-containing products takes place at moisture content above 7 – 8%

Table 2.3.3: Safe moisture content of oil-containing products.

Products	**Safe moisture content**
Groundnuts shelled	7%

Copra	7%
Palm kernels	5%
Cotton seed	10%

3.6.1Drying

Groundnuts, soybeans and sesame are first dried in the field with the leaves and stems still attached. Afterwards they are threshed or picked by hand. A moisture content of 15 % appears be the most suitable for picking by hand and threshing with flails or simple stripping machines. Threshing with hands and the use of simple stripping machines however, give a high percentage of broken groundnuts, which increase the chance of infection by fungi and insects. When threshing mechanically, it is possible to thresh at higher moisture content, which results in less damage. The picked or threshed products can be dried further on mats or canvas. If these products are stored in jute sacks, some additional drying will take place, provided the sacks are piled loosely. In the rainy season the additional drying should be done artificially. Storage of too moist products increases the possibility of internal heating.

Palm kernels are very difficult to store without loss of quality and have to be dried very well. For prolonged storage of coconuts the coconut meat should be dried from the original moisture content of about 50% to about 6%. The nuts are cut in half and are dried in the sun or artificially or by a combination of both. For sun-drying 60 – 80hours of sunshine are required; if it takes longer than 10 days the coconut will spoil. They are covered at night against dew formation and during rain, or the drying racks can be stored under a roof. The meat is removed from the shell after about 2 days and 3 - 5 days are then necessary to complete the drying. Artificial drying can be done with hot air. Temperatures above 77 °C should not be used, except in the initial stage; later, the temperature is reduced to 65 °C or less. Smoke affects the quality. Before drying artificially it is advisable to dry the halved nuts in the sun for 1 or 2 days.

3.6.3 Storage methods

Earthen pots and gourds, baskets, jute bags and silos are suitable for storage of oil-containing products. When using the airtight methods, it is important to have a very well dried product at the beginning of the storage period. In the humid tropics methods that allow ventilation have to be used where airtight storage is not possible.

Groundnuts have to be stored in the shell as much as possible, as this gives protection against insects and fungi. After shelling, quality and viability deteriorate rapidly. If jute sacks are use, the coarsely woven sacks prove to be better from the point of view of ventilation, but they increase the possibility of insect attack. Storage in big baskets is satisfactory.

4.0 Conclusion

High temperature and high moisture are the most significant factors affecting grain quality in storage. Each can cause rapid decline in germination, malting quality, baking quality, colour, oil composition, and many other quality characteristics. Development of insects is limited by temperatures below 15°C, and by moistures below 9% in cereal grains. Development of moulds is limited by high temperature.

5.0 Summary

High moisture and high temperature are the most significant factors affecting grain quality in storage. Each can cause rapid decline in germination, malting quality, baking quality, colour, oil composition, and many other quality characteristics.The safe moisture content for any particular grain may vary slightly depending on the variety. The mentioned safe moisture contents are valid for temperatures up to about 27 °C. Higher temperatures require lower moisture content maxima. Root crops, crops producing root or stem tubers, have special requirements with respect to storage, because of the high moisture content of the tubers (60 – 80% when fresh). On the one hand desiccation should be avoided; on the other hand one has to guard against too much humidity around the tubers, which may cause rotting. Living tubers continue to breathe fairly intensively, and this increases at higher temperatures.

Groundnuts, soybeans and sesame are first dried in the field with the foliage still attached. Afterwards they are threshed or picked by hand. Moisture content of 15% seems the most suitable for picking by hand and threshing with flails or simple stripping machines.

4.0Tutor Marked Assessment(TMA)

i. State the optimum temperature and humidity for the storage of grains.

ii. What are the two factors that determine the choice for the best storage of crops.

iii. List the different methods of temporary storage of cereals and pulses.

iv. Describe the three common methods of storing yam tubers.

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UNIT 2: METHODS OF REDUCING CROP DETERIORATION

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1.0 Introduction

In practice, preservation of procedures are aim at avoiding microbial and biochemical deterioration which are the principal forms of deterioration. Even with all recent progress In practice preservation procedures aim at avoiding microbiological and biochemical achieved in this field, no single one of these technological procedures applied alone can be considered wholly satisfactory from a microbiological, physio-chemical and organoleptic point of view, even if to a great extent the food value is assured.

2.0 Objectives

At the end of this unit you are expected to:

- Describe the different harvesting methods for different crops
- Explain the harvesting methods for cereals
- Understand how to harvest vegetables
- Describe the harvesting methods for tree crops
- Explain the harvesting methods for roots and tubers

3.0 Methods of reducing crop deterioration

Different methods have been employed to reduce crop deterioration. Some of these methods include physical, chemical and biochemical processes.

3.1 Technical methods of reducing crop deterioration

Table 2.3.1 Technical methods of reducing crop deterioration

Physical	Heating
	Cooling
	Lowering of water content drying/dehydration/concentration
	Sterilising filtration
	Irradiation
	Other physical means high pressure, vacuum, inert gasses
Chemical	Salting

	Smoking
	Sugar addition
	Artificial acidification
	Ethyl alcohol addition
	Antiseptic substance action
Biochemical	Lactic fermentation (natural acidification)
	Alcoholic fermentation

From the whole list of possible methods of reducing deterioration, over the years, some procedures for fruit and vegetable preservation have found practical application.

3.2 Procedures for fruit and vegetable preservation

Table 2.3.2 Procedures for fruit and vegetable preservation

Procedures	Practical applications
Fresh storage	Fruits and vegetables
Cold storage	Fruits and vegetables
Freezing	Fruits and vegetables
Drying/dehydration	Fruits and vegetables
Concentration	Fruits and vegetables juice
Chemical preservation	Fruits semi-processed
Preservation with sugar	Fruits products/preserve
Pasteurization	Fruits and vegetables juice
Sterilization	Fruits and vegetables
Sterilizing filtration	Fruits juices
Irradiation	Fruits and vegetables

These preservation procedures have two main characteristics as far as being applied to all food products is concerned:

- some of them are applied only to one or some categories of foods; others can be used across the board and thus a wider application (cold storage, freezing, drying/dehydration, sterilization, etc.).
- some guarantee food preservation on their own while others require combination with other procedures, either as principal or as auxiliary processes in order to assure preservation (for example smoking has to be preceded by salting).

3.2.1 Combined preservation procedures

In practice, preservation of procedures are aim at avoiding microbial and biochemical deterioration which are the principal forms of deterioration. Even with all recent progress In practice preservation procedures aim at avoiding microbiological and biochemical achieved in this field, no single one of these technological procedures applied alone can be considered wholly satisfactory from a microbiological, physio-chemical and organoleptic point of view, even if to a great extent the food value is assured.

Therefore, heat sterilization cannot be applied in order to destroy all microorganisms present in foods without inducing non desirable modifications. Preservation by dehydration/drying assures microbiological stability but has the drawback of undesirable modifications that appear during storage such as vitamin losses, oxidation phenomena, etc.

The principles of combined preservation procedures are:

- avoid or reduce secondary (undesirable) effects in efficient procedures for microbiological preservation;
- avoid qualitative degradation appearing during storage of products preserved by efficient procedures from a microbiological point of view;
- increase microbiological efficiency of preservation procedures by supplementary means;

- combine preservation procedures in order to obtain maximum efficiency from a microbiological point of view, by specific action on various types of micro-organisms present;
- establish combined factors that act simultaneously on bacterial cells.

Fresh fruit and vegetable storage can be combined with:

- storage in controlled atmosphere where carbon dioxide and oxygen levels are monitored, increasing concentration of CO_2 and lowering that of oxygen according to fruit species. Excellent results were obtained for pomace fruit; in particular the storage period for apples has been extended. Application of this combined procedure requires airtight storage rooms.
- storage in an environment containing ethylene oxide; this accelerates ripening in some fruit, e.g. tomatoes, bananas, mangoes, etc.

- Cold storage can be combined with storage in an environment with added of carbon dioxide, sulphur dioxide, etc. according to the nature of product to be preserved.
- Preservation by drying/dehydration can be combined with:

Freezing: fresh fruit and vegetables are dehydrated up to the point where their weight is reduced by 50% and then freezing preserves them.

This procedure (freeze-drying) combines the advantages of drying (reduction of volume and weight) with those of freezing (maintaining vitamins and to a large extent organoleptic properties).

A significant advantage of this process is the short drying time in so far as it is not necessary to go beyond the inflexion point of the drying curve. The finished products after de-freezing and rehydration/reconstitution are of a better quality compared with products obtained by dehydration alone.

- cold storage of dried/dehydrated vegetables in order to maintain vitamin C; storage temperature can be varied with storage time and can be at -8° C for a storage time of more than one year, with a relative humidity of 70-75 %.
- packaging under vacuum or in inert gases in order to avoid action of atmospheric oxygen;, mainly for products containing beta-carotene.
- Chemical preservation: a process used intensively for prunes and which has commercial applications is to rehydrate the dried product up to 35 % using a bath containing hot 2 % potassium sorbate solution. Another possible application of this combined procedure is the initial dehydration up to 35% moisture followed by immersion in same bath as explained above; this has the advantage of reducing drying time and producing minimum qualitative degradation. Both applications suppress the dehydrated products reconstitution (rehydration) step before consumption.
- Packaging in the presence of desiccants (calcium oxide, anhydrous calcium chloride, etc.) in order to reduce water vapour content in the package, especially for powdered products.
- Preservation by concentration, carried out by evaporation, is combined with cold storage during warm season for tomato paste (when water content cannot be reduced under the limit needed to inhibit molds and yeasts, e.g. a_w = 0.70...0.75).

Chemical preservation is combined with;

- acidification of food medium (lowering pH);
- using combined chemical preservatives;
- Preservation by lactic fermentation (natural acidification) can be combined with cold storage for pickles in order to prolong storage time or shelf-life;
- Preservation with sugar is combined with pasteurization for some preserves having sugar content below 65 %;

3.2.2 General procedures for fruit and vegetable preservation

Fresh storage

Fresh fruit and vegetable storage

Once fruit is harvested, any natural resistance to the action of spoiling microorganisms is lost. Changes in enzymatic systems of the fruit also occur on harvest, which may also accelerate the activity of spoilage organisms.

Means that are commonly used to prevent spoilage of fruits must include;

- care to prevent cutting or bruising of the fruit during picking or handling;
- refrigeration to minimize growth of micro-organisms and reduce enzyme activity;
- packaging or storage to control respiration rate and ripening;
- use of preservatives to kill micro-organisms on the fruit.

A principal economic loss occurring during transportation and/or storage of produce such as fresh fruit is the degradation, which occurs between the field and the ultimate destination due to the effect of respiration.

Methods to reduce such degradation are as follows;

- refrigerate the produce to reduce the rate of respiration;
- vacuum cooling;
- reduce the oxygen content of the environment in which the produce is kept to a value not above 5% of the atmosphere but above the value at which anaerobic respiration would begin. When the oxygen concentration is reduced within 60 minutes the deterioration is in practice negligible.

3.3 Recent developments in post-harvest technology of fresh fruits and vegetables

i. **Harvest maturity**: This is particularly important with fruit for export. One recent innovation is the measurement of resonant frequency of the fruit, which should enable the grading out of over mature and under-mature fruit before they are packed for export.

ii. **Harvest method:** Considerable research is continuing on mechanical harvesting of perishable crops with a view to minimizing damage. In fruit trees, controlling their height by use of dwarfing rootstocks, pruning and growth regulating chemicals will lead to easier, cheaper more accurate harvesting.

iii. **Handling systems**: Field packing of various vegetables for export has been carried out for many years. In the last decade or so this has been applied, in selected cases, to a few tropical fruit types. Where this system can be practiced it has considerable economic advantages in saving the cost of building, labour and equipment and can result in lower levels of damage into crops.

iv. **Pre-cooling**: Little innovation has occurred in crop pre-cooling over the last decade. However high velocity, high humidity forced air systems have continued to be developed and refined. These are suitable for all types of produce and are relatively simple to build and operate and, while not providing the speed of cooling of a vacuum or hydro cooler, have the flexibility to be used with almost all crops.

v. **Chemicals:** There is a very strong health lobby whose objective is to reduce the use of chemicals in agriculture and particularly during the postharvest period. Every year sees the prohibition of the use of commonly used post-harvest chemicals. New ways need to be developed to control post-harvest diseases, pest and sprouting.

vi. **Coatings:** Slowing down the metabolism of fruit and vegetables by coating them with a material which affects their gaseous exchange is being tested and used commercially on a number of products.

vii. **Controlled environment transport**: Recent innovations in this technique have produced great progress as a result of the development and miniaturization

viii. **Equipment to measure carbon dioxide and oxygen**: Several companies now offer containers where the levels of these two gases can be controlled very precisely.

3.4 Preservation by reduction of water content

a. Water and water activity (a_w) in foods

Microorganisms in a healthy growing state may contain in excess of 80% water. They get this water from the food in which they grow. If the water is removed from the food it also will transfer out of the bacterial cell and multiplication will stop. Partial drying will be less effective than total drying, though for some micro-organisms partial drying may be quite sufficient to arrest bacterial growth and multiplication.

Bacteria and yeasts generally require more moisture than molds, and so molds often will be found growing on semi-dry foods where bacteria and yeasts find conditions unfavourable; example are molds growing on partially dried fruits.

Slight differences in relative humidity in the environment in which the food is kept or in the food package can make great differences in the rate of micro-organism multiplication. Since micro-organisms can live in one part of a food that may differ in moisture and other physical and chemical conditions from the food just millimeters away, we must be concerned with conditions in the "microenvironment" of the micro-organisms. Thus it is common to refer to water conditions in terms of specific activity.

The term "**water activity"** is related to relative humidity. Relative humidity is defined as the ratio of the partial pressure of water vapour in the air to the vapour pressure of pure water at the same temperature. Relative humidity refers to the atmosphere surrounding a material or solution.

Water activity or aw is a property of solutions and is the ratio of vapour pressure of the solution compared with the vapour pressure of pure water at the same temperature. Under equilibrium conditions water activity equals:

$a_w = RH / 100$

When we speak of moisture requirements of microorganisms we really mean water activity in their immediate environment, whether this be in solution, in a particle of food or at a surface in contact with the atmosphere.

At the usual temperatures permitting microbial growth, most bacteria require a water activity in the range of about 0.90 to 1.00.

Some yeasts and molds grow slowly at a water activity down to as low as about 0.65.

Qualitatively, water activity is a measure of unbound, free water in a system available to support biological and chemical reactions. Water activity, not absolute water content, is what bacteria, enzymes and chemical reactants encounter and is affected by at the micro-environmental level in food materials.

3.5 Preservation by drying/dehydration

The technique of drying is probably the oldest method of food preservation practiced by mankind. The removal of moisture prevents the growth and reproduction of micro-organisms causing decay and minimizes many of the moisture mediated deterioration reactions.

It brings about substantial reduction in weight and volume minimizing packing, storage and transportation costs and enable storability of the product under ambient temperatures, features especially important for developing countries. The sharp rise in energy costs has promoted a dramatic upsurge in interest in drying worldwide over the last decade.

In osmotic dehydration the prepared fresh material is soaked in a heavy (thick liquid sugar solution) and/or a strong salt solution and then the material is sun or solar dried. During osmotic treatment the material loses some of its moisture. The syrup or salt solution has a protective effect on colour, flavour and texture.

This protective effect remains throughout the drying process and makes it possible to produce dried products of high quality. This process makes little use of sulphur dioxide.

3.5.1 Heat and mass transfer

Dehydration involves the application of heat to vaporize water and some means of removing water vapour after its separation from the fruit/vegetable tissues. Hence it is a combined/simultaneous (heat and mass) transfer operation for which energy must be supplied. A current of air is the most common medium for transferring heat to a drying tissue and convection is mainly involved.

The two important aspects of mass transfer are;

- the transfer of water to the surface of material being dried and
- the removal of water vapour from the surface.

In order to assure products of high quality at a reasonable cost, dehydration must occur fairly rapidly.

Four main factors affect the rate and total drying time:

- the properties of the products, especially particle size and geometry;
- the geometrical arrangement of the products in relation to heat transfer medium (drying air);
- the physical properties of drying medium/ environment;
- the characteristics of the drying equipment.

It is generally observed with many products that the initial rate of drying is constant and then decreases, sometimes at two different rates. The drying curve is divided into the constant rate period and the falling rate period.

3.5.2 Factors that influence the drying process

i. **Surface area**. Generally the fruit and vegetables to be dehydrated are cut into small pieces or thin layers to speed heat and mass transfer. Subdivision speeds drying for two reasons:

- large surface areas provide more surface in contact with the heating medium (air) and more surface from which moisture can escape;
- smaller particles or thinner layers reduce the distance heat must travel to the centre of the food and reduce the distance through which moisture in the centre of the food must travel to reach the surface and escape.

ii. Temperature. The greater the temperature difference between the heating medium and the food the greater will be the rate of heat transfer into the food, which provides the driving force for moisture removal. When the heating medium is air, temperature plays a second important role.

As water is driven from the food in the form of water vapour it must be carried away, or else the moisture will create a saturated atmosphere at the food's surface which will slow down the rate of subsequent water removal. The hotter the air the more moisture it will hold before becoming saturated.

Therefore, high temperature air in the vicinity of the dehydrating food will take up the moisture being driven from the food to a greater extent than will cooler air. Obviously, a greater volume of air also can take up more moisture than a lesser volume of air.

iii. Air velocity. Not only will heated air take up more moisture than cool air, but air in motion will be still more effective. Air in motion, that is, high velocity air, in addition to taking up moisture will sweep it away from the drying food's surface, preventing the moisture from creating a saturated atmosphere, which would slow down subsequent moisture removal. This is why clothes dry more rapidly on a windy day.

iv. Dryness of air. When air is the drying medium of food, the drier the air the more rapid is the rate of drying. Dry air is capable of absorbing and holding moisture. Moist air is closer to saturation and so can absorb and hold less additional moisture than if it were dry. But the dryness of the air also determines how low moisture content the food product can be dried to.

v. Atmospheric pressure and vacuum. If food is placed in a heated vacuum chamber the moisture can be removed from the food at a lower temperature than without a vacuum. Alternatively, for a given temperature, with or without vacuum, the rate of water removal from the food will be greater in the vacuum. Lower drying temperatures and shorter drying times are especially important in the case of heat-sensitive foods.

vi. Evaporation and temperature. As water evaporates from a surface it cools the surface. The cooling is largely the result of absorption by the water of the latent heat of phase change from liquid to gas.

In doing this the heat is taken from the drying air or the heating surface and from the hot food, and so the food piece or droplet is cooled.

vii. Time and temperature. Since all-important methods of food dehydration employ heat, and food constituents are sensitive to heat, compromises must be made between maximum possible drying rate and maintenance of food quality.

As is the case in the use of heat for pasteurization and sterilization, with few exceptions drying processes, which employ high temperatures for short times do less damage to food than drying processes employing lower temperatures for longer times.

Thus, vegetable pieces dried in a properly designed oven in four hours would retain greater quality than the same products sun dried over two days.

Several drying processes will achieve dehydration in a matter of minutes or even less if the food is sufficiently subdivided.

3.5.3 Drying techniques

Several types of dryers and drying methods, each better suited for a particular situation, are commercially used to remove moisture from a wide variety of food products including fruit and vegetables.

While sun drying of fruit crops is still practiced for certain fruit such as prunes, figs, apricots, grapes and dates, atmospheric dehydration processes are used for apples, prunes, and several vegetables; continuous processes as tunnel, belt trough, fluidized bed and foam-mat drying are mainly used for vegetables.

Spray drying is suitable for fruit juice concentrates and vacuum dehydration processes are useful for low moisture / high sugar fruits like peaches, pears and apricots.

Factors on which the selection of a particular dryer/ drying method depends include:

- form of raw material and its properties;
- desired physical form and characteristics of dried product;
- necessary operating conditions;
- operation costs.

There are three basic types of drying process:

- sun drying and solar drying;
- atmospheric drying including batch (kiln, tower and cabinet dryers) and continuous (tunnel, belt, belt-trough, fluidized bed, explosion puff, foam-mat, spray, drum and microwave);
- Sub-atmospheric dehydration (vacuum shelf/belt/drum and freeze dryers).

The scope has been expanded to include use of low temperature, low energy processes like osmotic dehydration. As far dryers are concerned, one useful division of dryer types separates them into air convection dryers, drum or roller dryers, and vacuum dryers.

Table 2.3.3: Common types of dryers used for liquid and solid foods.

Dryer type	**Usual food type**
Air convection dryers	
kiln	Pieces
Cabinet, tray or pan	pieces, purées, liquids
Tunnel	Pieces
Continuous conveyor belt	purées, liquids
Belt trough	Pieces
Air lift	small pieces, granules
Fluidized bed	small pieces, granules
Spray	liquid, purées
Drum or roller dryers	
Atmospheric	purées, liquids
Vacuum	purées, liquids

Vacuum dryers	
Vacuum shelf	pieces, purées, liquids
Vacuum belt	purées, liquids
freeze dryers	pieces, liquids

Source: Potter, 1984

3.5.4 Fruit and vegetable natural drying

1. Sun and solar drying

Natural drying for use until the next crop can be grown and harvested may preserve surplus production and specifically grown crops. Natural dried products can also be transported cheaply for distribution to areas where there are permanent shortages of fruit and vegetables.

The methods of producing sun and solar dried fruit and vegetables described here are simple to carry out and inexpensive. Grower, farmer, cooperative, etc. can easily employ them.

The best time to preserve fruits and vegetables is when there is a surplus of the product and when it is difficult to transport fresh materials to other markets. This is especially true for crops which are very easily damaged in transport and which stay in good condition for a very short time. Preservation extends the storage (shelf) life of perishable foods so that they can be available throughout the year despite their short harvesting season.

Sun and solar drying of fruits and vegetables is a cheap method of preservation because it uses the natural resource/ source of heat: sunlight. This method can be used on a commercial scale as well at the village level provided that the climate is hot, relatively dry and free of rainfall during and immediately after the normal harvesting period. The fresh crop should be of good quality and as ripe (mature) as it would need to be if it was going to be used fresh. Poor quality produce cannot be used for natural drying.

Dried fruit and vegetables have certain advantages over those preserved by other methods. They are lighter in weight than their corresponding fresh produce and, at the same time, they do not require refrigerated storage. However, if they are kept at high temperatures and have high moisture content they will turn brown after relatively short periods of storage.

Different lots at various stages of maturity (ripeness) must not be mixed together; this would result in a poor dried product. Some varieties of fruit and vegetables are better for natural drying than other; they must be able to withstand natural drying without their texture becoming tough so that they are not difficult to reconstitute. Some varieties are unsuitable because they have irregular shape and there is a lot of wastage in trimming and cutting such varieties.

Damaged parts, which have been attacked by insects, rodents, diseases, etc., and parts, which have been discoloured or have a bad appearance or colour, must be removed. Before trimming and cutting, most fruit and vegetables must be washed in clean water. Onions are washed after they have been peeled.

Trimming includes the selection of the parts, which are to be dried, cutting off and disposing of all unwanted material. After trimming, the greater part of the fruit and vegetables cut into even slices of about 3 to 7 mm thick or in halves/quarters, etc.

It is very important to have all slices/parts in one drying lot of the same thickness/size; the actual thickness will depend on the kind of material. Uneven slices or different sizes dry at different rates and this result in a poor quality end product. Onions and root crops are sliced with a hand slicer or vegetable cutter; bananas, tomatoes and other vegetables or fruit are sliced with stainless-steel knives.

Some fruit and vegetables, in particular bananas, apples and potatoes, go brown very quickly when left in the air after peeling or slicing; this discoloration is due to an active enzyme called **phenoloxidase**. To prevent the slices from going brown they must be kept under water until drying can be started. Salt or sulphites in solution give better protection. However, whichever method is used, further processing should follow as soon as possible after cutting or slicing.

The main problems for sun drying are dust, rain and cloudy weather. Therefore, drying areas should be dust-free and whenever there is a threat of a dust storm or rain, the drying trays should be stacked together and placed under cover.

In order to produce dust-free and hygienically clean products, fruit and vegetable material should be dried well above ground level so that dust, insects, livestock or people does not contaminate them. All materials should be dried on trays designed for the purpose; the most common drying trays have wooden frames with a fitted base of nylon mosquito netting. Mesh made of woven grass can also be used. Metal netting must not be used because it discolours the product.

The trays should be placed on a framework at table height from the ground. This allows the air to circulate freely around the drying material and it also keeps the food product well away from dirt. Ideally the area should be exposed to wind and this speed up drying, but this can only be done if the wind is free of dust.

3.5.5 Blanching

Exposing fruit and vegetable to hot or boiling water - as a pre-treatment before drying has the following advantages:

- it helps clean the material and reduce the amount of micro-organisms present on the surface;
- it preserves the natural colour in the dried products; for example, the carotenoid (orange and yellow) pigments dissolve in small intracellular oil drops during blanching and in this way they are protected from oxidative breakdown during drying;
- it shortens the soaking and/or cooking time during reconstitution.

During hot water blanching, some soluble constituents are leached out: water-soluble flavours, vitamins (vitamin C) and sugars. With potatoes this may be an advantage as leaching out of sugars makes the potatoes less prone to turning brown.

Blanching is a delicate processing step; time, temperature and the other conditions must be carefully monitored.

A suitable water-blanching method in traditional processing is as follows:

- the sliced material is placed on a square piece of clean cloth; the corners of the cloth are tied together;
- a stick is put through the tied corners of the cloth;
- the cloth is dipped into a pan containing boiling water and the stick rests across the top of the pan thus providing support for the cloth bag.

The average blanching time is 6 minutes. The start of blanching has to be timed from the moment the water starts to boil again after the cloth bag has been dipped into the pan. While the material is being blanched the cloth bag should be raised and lowered in the water so that the material is heated evenly.

When the blanching time is completed the cloth bag and its content should be dipped into cold water to prevent over-blanching. If products are over-blanched (boiled for too long) they will stick together on the drying trays and they are likely to have a poor flavour.

Green beans, carrots, okra, turnip and cabbage should always be blanched. The producer can choose whether or not potatoes need blanching. Blanching is not needed for onions, leeks, tomatoes and sweet peppers. Tomatoes are dipped into hot water for one minute when they need to be peeled but this is not blanching. As a rule fruits are not blanched.

4.0 Conclusion

The choice of method of storage depend the moisture content of the product when it comes from the field and the relative humidity of the outside air during the storage period. Slight differences in relative humidity in the environment in which the food is kept or in the food package can make great differences in the rate of microorganism multiplication. In practice food preservation procedures aim at avoiding microbiological and biochemical deterioration, which are the principal forms of deterioration. Microorganisms in a healthy growing state may contain in excess of 80% water. They get this water from the food in which they grow. If the water is removed from the food it also will transfer out of the bacterial cell and multiplication will stop.

Partial drying will be less effective than total drying, though for some micro-organisms partial drying may be quite sufficient to arrest bacterial growth and multiplication.

5.0 Summary

High temperature and high moisture are the most significant factors affecting grain quality in storage. Each can cause rapid decline in germination, malting quality, baking quality, colour, oil composition, and many other quality characteristics. Insects and moulds impair the quality of grain directly by their feeding and development, and indirectly through generation of heat and moisture. High temperatures and moistures favour development of insects and moulds. Development of insects is limited by temperatures below 15°C, and by moistures below 9% in cereal grains. Development of moulds is limited by temperatures below 10°C, and by moistures below 13% in cereal grains. Spraying with insecticides or fumigating minimises insect problems but leaves chemical residues in grain, which break down with time. Presence of residues, and their concentration, affects acceptability of the grain to markets. Various methods of storage have evolved over time and depending on crops to be stored and the environmental conditions. Food preservation techniques cold storage, freezing, drying/dehydration, sterilization, etc. are applied only to one or some categories of foods; others can be used across the board and thus a wider application. Some guarantee food preservation on their own while others require combination with other procedures, either as principal or as auxiliary processes in order to assure preservation (for example smoking has to be preceded by salting).

Exposure of fruits and vegetables to ionizing radiation slows their rate of ripening, to inhibit sprouting and thereby extend the shelf life of potatoes, onions and garlic. It is very important from a practical point of view to avoid any product contamination after boiling and to assure a hygienic operation of the whole technological process (this will contribute to the prevention of product molding or fermentation).

6.0Tutor Marked Assessment (TMA)

- Describe three technical methods of reducing crop deterioration
- Explain the principles of combined preservation procedures
- List four factors that affect the rate and total drying time of crop products

- Explain the advantages of blanching

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UNIT 3: USE OF PRESERVATIVES

6.0 Tutor Marked Assignment (TMA)

7.0 References and Further Readings

1.0 Introduction

Preservatives are used to improve the colour and keeping qualities of the final product for some fruits and vegetables. Preservatives include items such as sulphur dioxide, ascorbic acid, citric acid, salt and sugar and can either be simple or compound solutions. The concept of combinations of preservatives and treatments to preserve foods is frequently called the **hurdle or barrier concept**. Combinations of additives and preservatives systems provide unlimited preservation alternatives for applications in food products to meet consumer demands for healthy and safe foods.

2.0 Objectives

At the end of this unit you should be able to:

- Describe the different methods of preserving crop produce
- Explain the latest handling procedures for crop produce
- Describe chemical method of preservation of crop produce
- Preserve fruits by the dehydration
- Preserve fruit by acidification

3.0 Use of preservatives.

Treatment with preservatives takes place after blanching or, when blanching is not needed, after slicing. In traditional, simple processing the method recommended is:

- put enough preservative solution to cover the cloth bag into a container/pan;
- dip the bag containing the product into the preservative solution for the amount of time specified;
- remove the bag and put it on a clean tray while the liquid drains out. The liquid which drains out must not go back into the preservative solution because it would weaken the solution.

Care must be taken after each dip to refill the container to the original level with fresh preservative solution of correct strength. After five lots of material have been dipped, the remaining solution is thrown away; i.e. a fresh lot of preservative solution is needed for every 5 lots of material. The composition and strength of the preservative solution vary for different fruit and vegetables. The strength of sulphur dioxide is expressed as "parts per million" (ppm). 1.5 grams of sodium meta-bisulphite in one litre of water gives 1000 ppm of sulphur dioxide.

Sodium bicarbonate is added to the blanching water when okra, green peas and some other green vegetables are blanched. The chemical raises the pH of the blanching water and prevents the fresh green colour of chlorophyll being changed into pheophytin, which is unattractive brownish-green. The preservative solutions in the fruit and vegetable pre-treatment can only be used in enameled, plastic or stainless steel containers; never use ordinary metal because solutions will corrode this type of container.

As a general rule, **preservatives are not used for treating onions, garlic, leeks, chilies and herbs**

3.9 Chemical preservation

Many chemicals will kill microorganisms or stop their growth but most of these are not permitted in foods. Chemical food preservatives are those substances which are added in very low quantities (up to 0.2%) and which do not alter the organoleptic and physio-chemical properties of the foods at or only very little.

Preservation of food products containing chemical food preservatives is usually based on the combined or synergistic activity of several additives, intrinsic product parameters (e.g. composition, acidity, water activity) and extrinsic factors (e.g. processing temperature, storage atmosphere and temperature). This approach minimizes undesirable changes in product properties and reduces concentration of additives and extent of processing treatments.

The concept of combination of preservatives and treatments to preserve foods is frequently called the **hurdle or barrier concept**. Combination of additives and preservatives provide unlimited preservation alternatives for applications in food products to meet consumer demands for healthy and safe foods.

Chemical food preservatives are applied to foods as direct additives during processing, or develop by themselves during processes such as fermentation. Certain preservatives have been used either accidentally or intentionally for centuries, and include sodium chloride (common salt), sugar, acids, alcohols and components of smoke. In addition to preservation, these compounds contribute to the quality and identity of the products, and are applied through processing procedures such as salting, curing, fermentation and smoking.

3.9.1 Traditional chemical food preservatives

Traditional chemical food preservatives and their use in fruit and vegetable processing technologies could be summarized as follows:

- common salt: brined vegetables;
- sugars (sucrose, glucose, fructose and syrups);
- foods preserved by high sugar concentrations: jellies, preserves, syrups, juice concentrates;
- interaction of sugar with other ingredients or processes such as drying and heating;
- indirect food preservation by sugar in products where fermentation is important (naturally acidified pickles and sauerkraut).
- Acidulants and other preservatives formed in or added to fruit and vegetable products are as follows:
- Lactic acid. This acid is the main product of many food fermentations; it is formed by microbial degradation of sugars in products such as sauerkraut and pickles. The acid produced in such fermentations decreases the pH to levels unfavourable for growth of spoilage organisms such as putrefactive anaerobes and butyric-acid-producing bacteria. Yeasts and molds that can grow at such pH levels can be controlled by the inclusion of other preservatives such as sorbate and benzoate.
- Acetic acid. Acetic acid is a general preservative inhibiting many species of bacteria, yeasts and to a lesser extent molds. It is also a product of the lactic-acid fermentation,

and its preservative action even at identical pH levels is greater than that of lactic acid. The main applications of vinegar (acetic acid) includes products such as pickles, sauces and ketchup.

- Other acidulants

- Malic and tartaric (tartric) acids is used in some countries mainly to acidify and preserve fruit sugar preserves, jams, jellies, etc.
- Citric acid is the main acid found naturally in citrus fruits; it is widely used (in carbonated beverages) and as an acidifying agent of foods because of its unique flavour properties. It has an unlimited acceptable daily intake and is highly soluble in water. It is a less effective antimicrobial agent than other acids.
- Ascorbic acid or vitamin C, its isomer isoascorbic or erythorbic acid and their salts are highly soluble in water and safe to use in foods.
- Commonly used lipophilic acid food preservatives
- Benzoic acid in the form of its sodium salt, constitutes one of the most common chemical food preservative. Sodium benzoate is a common preservative in acid or acidified foods such as fruit juices, syrups, jams and jellies, sauerkraut, pickles, preserves, fruit cocktails, etc. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.
- Sorbic acid is generally considered non- toxic and is metabolized; among other common food preservatives the WHO has set the highest acceptable daily intake (25 mg/kg body weight) for sorbic acid. Sorbic acid and its salts are practically tasteless and odourless in foods, when used at reasonable levels (< 0.3 %) and their antimicrobial activity is generally adequate.
- Sorbates are used for mould and yeast inhibition in a variety of foods including fruits and vegetables, fruit juices, pickles, sauerkraut, syrups, jellies, jams, preserves, high moisture dehydrated fruits, etc. Potassium sorbate, a white, fluffy powder, is very soluble in water (over 50%) and when added to acid foods it is hydrolyzed to the acid form. Sodium and calcium sorbates also have preservative activities but their application is limited compared to that for the potassium salt, which is employed because of its stability, general ease of preparation and water solubility.

3.9.2 Gaseous chemical food preservatives

1. Sulphur dioxide and sulphites. Sulphur dioxide (SO_2) has been used for many centuries as a fumigant and especially as a wine preservative. It is a colourless, suffocating, pungent-smelling, non-flammable gas and is very soluble in cold water (85 g in 100 ml at 25°C).
2. Sulphur dioxide and its various sulphites dissolve in water, and at low pH levels yield sulphuric acid, bisulphite and sulphite ions. The various sulphite salts contain 50-68% active sulphur dioxide. A pH dependent equilibrium is formed in water and the proportion of SO_2 ions increases with decreasing pH values. At pH values less than 4.0 the antimicrobial activity reaches its maximum.
3. Sulphur dioxide is used as a gas or in the form of its sulphite, bisulphite and metabisulphite salts which are powders. The gaseous form is produced either by burning Sulphur or by its release from the compressed liquefied form.
4. Metabisulphite are more stable to oxidation than bisulphites, which in turn show greater stability than sulphites.
5. The antimicrobial action of sulphur dioxide against yeasts, moulds and bacteria is selective, with some species being more resistant than others.
6. Sulphur dioxide and sulphites are used in the preservation of a variety of food products. In addition to wines these include dehydrated/dried fruits and vegetables, fruit juices, acid pickles, syrups, semi-processed fruit products, etc. In addition to its antimicrobial effects, sulphur dioxide is added to foods for its antioxidant and reducing properties, and to prevent enzymatic and non-enzymatic browning reactions.
7. Carbon dioxide (CO_2) is a colourless, odourless, non-combustible gas, acidic in odour and flavour. In commercial practice it is sold as a liquid under pressure (58 kg per cm^3) or solidified as dry ice.
8. Carbon dioxide is used as a solid (dry ice) in many countries as a means of low-temperature storage and transportation of food products. Beside keeping the temperature low, as it sublimes, the gaseous CO_2 inhibits growth of psychrotrophic micro-organisms and prevents spoilage of the food (fruits and vegetables, etc.).

9. Carbon dioxide is used as a direct additive in the storage of fruits and vegetables. In the controlled/ modified environment storage of fruit and vegetables, the correct combination of O_2 and CO_2 delays respiration and ripening as well as retarding mould and yeast growth. The final result is an extended storage of the products for transportation and for consumption during the off-season. The amount of CO_2 (5-10%) is determined by factors such as nature of product, variety, climate and extent of storage.
10. Chlorine. The various forms of chlorine constitute the most widely used chemical sanitiser in the food industry. These chlorine forms include chlorine (Cl_2), sodium hypochlorite (NaOCl), calcium hypochlorite ($Ca(OCl)_2$) and chlorine dioxide gas (ClO_2).These compounds are used as water adjuncts in processes such as product washing, transport, and cooling of heat-sterilized cans; in sanitizing solutions for equipment surfaces, etc. Important applications of chlorine and its compounds include disinfection of drinking water and sanitation of food processing equipment.

3.9.3 General rules for chemical preservation

i. Chemical food preservatives have to be used only at a dosage level which is needed for a normal preservation and not more.
ii. Reconditioning" of chemical preserved food, e.g. a new addition of preservative in order to stop a microbiological deterioration already occurred is not recommended.
iii. The use of chemical preservatives must be strictly limited to those substances which are recognized as being without harmful effects on human beings' health and are accepted by national and international standards and legislation.

Factors influencing the action of chemical food preservatives

i. Factors related to chemical preservatives are:
   a. chemical composition;
   b. concentration.

ii. Factors related to microorganisms:

a) Microorganism species; as a general rule it is possible to take the following facts as a basis:

- sulphur dioxide and its derivatives can be considered as an "universal" preservative; they have an antiseptic action on bacteria as well as on yeasts and moulds;
- benzoic acid and its derivatives have a preservative action which is stronger against bacteria than on yeasts and moulds;
- sorbic acid acts on moulds and certain yeast species; in higher dosage levels it acts also on bacteria, except lactic and acetic ones;
- formic acid is more active against yeasts and moulds and less on bacteria.

b) The initial number of micro-organisms in the treated product determines the efficiency of the chemical preservative. The efficiency is less if the product has been contaminated because of preliminary careless hygienic treatment or an incipient alteration. Therefore, with a low initial number of microorganisms in the product, the preservative dosage level could be reduced.

iii. Specific factors related to the product to be preserved:

a. product chemical composition;
b. influence of the pH value of the product: the efficiency of the majority of chemical preservatives is higher at lower pH values, i.e. when the medium is more acidic.
c. Physical presentation and size which the product is sliced to: the chemical preservative's dispersion in food has an impact on its absorption and diffusion through cell membranes on micro-organisms and this determines the preservation effect. Therefore, the smaller the slicing of the product, the higher the preservative action. Preservative dispersion is slowed down by viscous foods (concentrated fruit juices, etc.)

iv. Miscellaneous factors

a. Temperature: chemical preservative dosage level will be established as a function of product temperature and characteristics of the micro-flora;
b. Time: at preservative dosage levels in employed in industrial practice, the time period needed in order to obtain a "chemical sterilization" is a few weeks for benzoic acid and shorter for sulphurous acid.

TABLE 2.3.9 Chemical Food Preservatives

Agent	Acceptable Daily intake (mg/Kg body weight)	Commonly used levels (%)
Lactic acid	No limit	No limit
Citric acid	No limit	No limit
Acetic acid	No limit	No limit
Sodium Diacetate	15	0.3-0.5
Sodium benzoate	5	0.03-0.2
Sodium propionate	10	0.1-0.3
Potassium sorbate	25	0.05-0.2
Methyl paraben	10	0.05-0.1
Sodium nitrite	0.2	0.01-0.02
Sulphur dioxide	0.7	0.005-0.2

Source: FDA, 1991

Some food products in common usage are summarized as follows:

i. Citric acid: fruit juices; jams; other sugar preserves;

i. Acetic acid: vegetable pickles; other vegetable products;
ii. Sodium benzoate: vegetable pickles; preserves; jams; jellies; semi-processed products;
iii. Sodium propionate: fruits; vegetables;
iv. Potassium sorbate: fruits; vegetables; pickled products; jams, jellies;
v. Methyl paraben: fruit products; pickles; preserves;
vi. Sulphur dioxide: fruit juices; dried / dehydrated fruits and vegetables; semi-processed products.

3.10 Preservation of vegetables by acidification

Food acidification is a means of preventing their deterioration in so far as a non-favourable medium for micro-organisms development is created. This acidification can be obtained by two ways: natural acidification and artificial acidification.

A. Natural acidification.

This is achieved by a predominant lactic fermentation which assures the preservation based on acidoceno-anabiosys principle which is preservation by lactic fermentation is called also biochemical preservation.

Throughout recorded history food has been preserved by fermentation. In spite of the introduction of modern preservation methods, lactic acid fermented vegetables still have a great popularity, mainly because of their nutritional and gastronomic qualities.

The various preservation methods discussed so far that are based on the application of heat, removal of water, cold and other principles, all have the common objective of decreasing the number of living organisms in foods or at least holding them in check against further multiplication.

Fermentation processes for preservation purposes, in contrast, encourage the multiplication of microorganisms and their metabolic activities in foods. But the organisms that are encouraged are from a select group and their metabolic activities and end products are highly desirable.

There are some characteristic features in the production of fermented vegetables, which will be pointed out below using cucumbers as an example. In the production of lactic acid fermented cucumbers, the raw material is put into brine without previous heating. Through the effect of salt and oxygen deficiency the cucumber tissues gradually die. At the same time, the semi-permeability of the cell membranes is lost, whereby soluble cell components diffuse into the brine and serve as food substrate for the microorganisms.

Under such specific conditions of the brine the lactic acid bacteria succeed in overcoming the accompanying microorganisms and lactic acid as the main metabolic products is formed. Under favourable conditions (for example moderate salt in the brine, use of starter cultures) it takes at least 3 days until the critical pH value of 4.1 or less - desired for microbiological reasons - is reached.

B. Artificial acidification

This is carried out by adding acetic acid which is the only organic acid harmless for human health and stable in specific working conditions; in this case biological principles of the preservation are acidoanabiosys and, to a lesser extent, acidoabiosys.

C. Combined acidification is a preservation technology which involves as a preliminary processing step a weak lactic fermentation followed by acidification (vinegar addition).

The two main classes of vegetables preserved by acidification are sauerkraut and pickles;

a) may be canned by processing sufficiently by heat to assure preservation in hermetically sealed containers; or

b) may be packaged in sealed containers and preserved with or without the addition of benzoate of soda or any other ingredient permissible under the provisions of Food and Drug Administration (FDA).

3.11 Preservation with sugar

The principle of this technology is to add sugar in a quantity that is necessary to augment the osmotic pressure of the product's liquid phase at a level which will prevent microorganism development.

From a practical point of view, however, it is usual to partially remove water (by boiling) from the product to be preserved, with the objective of obtaining a higher sugar concentration. In concentrations of 60% in the finished products, the sugar generally assures food preservation.

In the food preservation with sugar, the water activity cannot be reduced below 0.845. This value is sufficient for bacteria and neosmophile yeast inhibition but does not prevent mold attack. For this reason, various means are used to avoid mold development:

- finished product pasteurization (jams, jellies, etc.);
- use of chemical preservatives in order to obtain an antiseptic product surface.

It is very important from a practical point of view to avoid any product contamination after boiling and to assure a hygienic operation of the whole technological process (this will contribute to the prevention of product molding or fermentation). Storage of the finished products in good conditions can only be achieved by ensuring the above level of water activity

3.12 Heat preservation/heat processing

Various degrees of preservation

There are various degrees of preservation by heating; a few terms have to be identified and understood.

a. **Sterilization:** By sterilization we mean complete destruction of micro-organisms. Because of the resistance of certain bacterial spores to heat, this frequently means a treatment of at least 121° C (250° F) of wet heat for 15 minutes or its equivalent. It also means that every particle of the food must receive this heat treatment. If a can of food is to be sterilized, then immersing it into a 121° C pressure cooker or retort for the 15 minutes will not be sufficient because of relatively slow rate of heat transfer through the food in the can to the most distant point.
b. **"Commercially sterile**": This term describes the condition that exists in most of canned or bottled products manufactured under good manufacturing practices procedures and methods. These products generally have a shelf-life of two years or more.
c. **Pasteurization:** Means a comparatively low order of heat treatment, generally at a temperature below the boiling point of water. The more general objective of pasteurization is to extend product shelf-life from a microbial and enzymatic point of view. This is the objective when fruit or vegetable juices and certain other foods are pasteurized. Pasteurization is frequently combined with another means of preservation - concentration, chemical, acidification, etc.

d. **Blanching:** This is a type of pasteurization usually applied to vegetables mainly to inactivate natural food enzymes. Depending on its severity, blanching will also destroy some microorganisms.

3.13 Food irradiation

Food irradiation is one of the food processing technologies available to the food industry to control organisms that cause food-borne diseases and to reduce food losses due to spoilage and deterioration. Food irradiation technology offers some advantages over conventional processes. Each application should be evaluated on its own merit as to whether irradiation provides a technical and economical solution that is better than traditional processing methods.

Shelf-life extension: Irradiation can extend the shelf-life of foods in a number of ways. By reducing the number of spoilage organisms (bacteria, mold, and fungi), irradiation can lengthen the shelf life of fruits and vegetables.

Since ionizing radiation interferes with cell division, it can be used as an alternative to chemicals to inhibit sprouting and thereby extend the shelf life of potatoes, onions and garlic. Exposure of fruits and vegetables to ionizing radiation slows their rate of ripening. Strawberries, for example, have been found to be suitable for irradiation. Their shelf-life can be extended three-fold, from 5 to 15 days.

Disinfestations ionizing radiation can also be used as an alternative to chemical fumigants for disinfestations of grains, spices, fruits and vegetables. Many countries prohibit the importation of products suspected of being contaminated with live insects to protect the importing country's agricultural base. With the banning of certain chemical fumigants, irradiation has the potential to facilitate the international shipment of food products.

4.0 Conclusion

The choice of method of storage depend the moisture content of the product when it comes from the field and the relative humidity of the outside air during the storage period. Slight differences in relative humidity in the environment in which the food is kept or in the food package can make great differences in the rate of micro-organism multiplication.In practice food preservation procedures aim at avoiding microbiological and biochemical deterioration, which are the principal forms of deterioration. Microorganisms in a healthy growing state may contain in excess of 80% water. They get this water from the food in which they grow. If the water is removed from the food it also will transfer out of the bacterial cell and multiplication will stop. Partial drying will be less effective than total drying, though for some micro-organisms partial drying may be quite sufficient to arrest bacterial growth and multiplication.

5.0 Summary

High temperature and high moisture are the most significant factors affecting grain quality in storage. Each can cause rapid decline in germination, malting quality, baking quality, colour, oil composition, and many other quality characteristics. Insects and moulds impair the quality of grain directly by their feeding and development, and indirectly through generation of heat and moisture. High temperatures and moistures favour development of insects and moulds. Development of insects is limited by temperatures below 15°C, and by moistures below 9% in cereal grains. Development of moulds is limited by temperatures below 10°C, and by moistures below 13% in cereal grains.Spraying with insecticides or fumigating minimises insect problems but leaves chemical residues in grain, which break down with time. Presence of residues, and their concentration, affects acceptability of the grain to markets. Various methods of storage have evolved over time and depending on crops to be stored and the environmental conditions. Food preservation techniques cold storage, freezing, drying/dehydration, sterilization, etc are applied only to one or some categories of foods; others can be used across the board and thus a wider application. Some guarantee food preservation on their own while others require combination with other procedures, either as principal or as auxiliary processes in order to assure preservation (for example smoking has to be preceded by salting).

Exposure of fruits and vegetables to ionizing radiation slows their rate of ripening, to inhibit sprouting and thereby extend the shelf life of potatoes, onions and garlic. It is very important from a practical point of view to avoid any product contamination after boiling and to assure a hygienic operation of the whole technological process (this will contribute to the prevention of product molding or fermentation).

6.0 Tutor Marked Assignment (TMA)

i. Describe food irradiation as a method of food preservation
ii. Describe heat processing as a method of food preservation
iii. Describe sugar as a means food preservation
iv. Describe the preservation of vegetables by acidification
v. Describe chemical means of preservation of fruits and vegetables
vi. Describe preservation by reduction of water content

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UNIT 4: PRINCIPLES OF TRANSPORTATION

Table of Contents

1.0 Introduction

Transportation systems are important in moving fresh produce from production areas to distribution points. Transportation facilitates the rapid movement of fresh produce within the horticultural supply chain. Fresh produce must be properly protected during transportation in order to minimize mechanical damage, temperature abuse, taint and contamination by food-borne pathogens. It is the responsibility of the transport provider to ensure that the transport vehicle is well maintained and is in a hygienic condition. The quality of perishable produce can be adversely affected by a lack of standard hygiene in transportation

2.0 Objection

At the end of studying this unit you would be able to:

- Have a clear understanding of the factors that affect quality of produce during transportation
- Explain hygiene in transport system
- Distinguish the factors that govern selection of mode of transport
- Have an understanding of how to handle whole sale and retail outlets

3.0 Transportation of crop produce

Transportation facilitates the rapid movement of fresh produce within the horticultural supply chain. Fresh produce must be properly protected during transportation in order to minimize mechanical damage, temperature abuse, taint and contamination by food-borne pathogens. It is the responsibility of the transport provider to ensure that the transport vehicle is well maintained and is in a hygienic condition.

3.1 Factors that may compromise quality during transportation

3.1.1 Mechanical damage

Mechanical damage of fresh produce results in tissue darkening or colour changes on the skin of the commodity and markedly affects its nutritional and sensory quality, i.e. its taste, texture, appearance and flavour. Mechanical damage can also lead to moisture loss, pathogen invasion and can stimulate the production of ethylene, which triggers the senescence process in horticultural crops such as apples, papayas and tomatoes.

Types of mechanical damage that occur during transportation

i. Impact damage occurs due to:

• collision between produce items or between produce and hard surfaces;
• rapid acceleration or deceleration, e.g. when fruits are dropped; or
• Exertion or removal of forces (such as impact, compression, vibration and abrasion) within a short time (duration impact).

Impact damage can result in bruising with or without skin injury.

ii. Compression damage

• occurs when produce is subjected to heavy commodity weight, with or without physical movement, as occurs when containers are of inappropriate depth, over-packed, packed in containers of poor structural integrity, improperly packed or stacked too high;
• generally results in distortion cracks and splits;
• is usually caused by package failure; and
• is also caused by stacking or sitting on top of produce.

iii. Abrasion damage

• occurs when the surfaces of produce slide across another surface causing friction;
• can result in removal of the cuticle and wax layers of produce; and
• can be minimized with the use of lining or padding materials, such as paper or sleeves to protect the produce.

iv. Vibration damage:

The level of vibration of a moving vehicle is greatly influenced by the nature of the road and the suspension system of that vehicle. Vibration occurs when produce moves repeatedly for prolonged periods within a container during transport. Vibration can result in damage due to compression, impact and abrasion.

v. Vibration damage can be prevented, or limited, by the following practices:

• Use plastic crates for transportation – vibration damage is less with plastic crates than with cartons since plastic crates absorb and dissipate the force, thereby keeping the effects of vibration within the crate.

• Use rigid containers to limit the movement of the base of the container in the transport vehicle.

• Use a vehicle with a firm suspension system.

• Use radial tires, which absorb more impact than other types for road transport.

vi. Minimizing mechanical damage

Mechanical damage can be minimized through the use of packaging that can withstand:

• rough handling during loading and unloading;

• compression from the overhead weight of other containers;

• impact and vibration during transportation; and

• high humidity during pre-cooling, transit and storage.

3.1.2 Overheating

Overheating occurs as a result of external sources (such as the sun, heat from the road, the walls of the vehicle etc.) as well as from heat generated by the produce within the transport vehicle. Overheating causes natural breakdown and decay and increases the rate of water loss from the produce. Overheating can, therefore, result in overall quality loss.

i. Factors that contribute to overheating include:

• heat generated by the produce due to respiration;

• lack of ventilation, as occurs in closed vehicles;

• restricted movement of air between and through packages;

• lack of adequate ventilation in packaging; and

• exposure of packaged produce to the sun while waiting to be transported or unloaded.

ii. **Overheating can be avoided by:**

• use of well-ventilated vehicles;

• proper stacking to allow for the disposal of heat;

• use of well-ventilated packaging;

• avoidance of exposure to the sun on loading and off-loading tarmacs; and

• travelling early in the morning or at night if non-refrigerated transport is used.

iii. Loading patterns in transport systems to minimize overheating

Stacking patterns in transport vehicles should minimize contact between the produce and the floor and wall surfaces of the vehicle to reduce the transmission of heat from the outside of the vehicle into the loaded produce. Centre-loading leaves an insulating air space between the load and the outside walls of the vehicle.

Produce transported in cartons should be stacked to allow adequate air circulation throughout the load. The industry norm is to load palletized fruit, i.e. fruit in cartons placed on a pallet. Palletization makes loading easier and more cost effective than loading loose cartons into the container. Palletizing is usually done after other pre-cooling methods, but before forced air-cooling. Pallets must, however, be properly secured by strapping, corner bracing or net wrapping.

3.1.3Build- up of gases in the transport system

Inadequate air circulation during the transportation of fresh produce can lead to the buildup of ethylene or carbon dioxide. Care must therefore be taken to assure proper ventilation within the transportation vehicle in order to avoid gas build up.

Transportation of mixed loads

Mixed loads can be of serious concern when temperature optima are not compatible or when ethylene-producing commodities and ethylene-sensitive commodities are transported together. Wet and dry produce items must be transported in separate mixed loads in order to avoid the transfer of contamination from wet to dry produce.

3.2Hygiene in transport systems

The quality of perishable produce can be adversely affected by a lack of standard hygiene in transportation systems. Soil, typically found in a field, can encrust the floor area of the transport system. In order to prevent contamination by food-borne pathogens, transport systems should make use of good sanitation practices, ensure proper temperature and humidity management and minimize potential damage to the produce. It is critical that all vehicles used for transportation of food products are cleaned and washed routinely to remove decaying remains of agricultural produce. Water, used for washing, must be safe and clean. If pallets are cleaned by fumigation, only recommended/permitted fumigants or chemicals must be used and such use must be according to the manufacturers' recommendations.

3.3 Factors that govern the selection of the mode of transportation

The mode of transportation is influenced by:

- The destination of the produce
- The value of the produce
- The degree of perishability
- The volume of produce to be transported
- Recommended storage temperature and relative humidity conditions for the load
- Ambient temperature conditions at origin and destination points
- Time in transit to reach the destination by air, land or sea transport
- Road access
- Freight rates
- Quality of the transportation service

3.4Transport equipment

Equipment used for the transport of fresh produce include:

- Refrigerated and non-refrigerated vehicles – for highway transport
- Containers for air, rail and highway transport, and for lift-on/lift-off ocean transport
- Break bulk refrigerated vessels – for handling palletized loads in the refrigerated holds of vessels
- Pallets – for air cargo and highway transport
- Horse carts, donkeys
- Wheelbarrows and carts – for transportation over distances of 1-8km

Refrigerated and non-refrigerated vehicles. Refrigerated or non-refrigerated vehicles can be used for the bulk transportation of fresh produce.

i. Non-refrigerated vehicles

Non-refrigerated vehicles must provide sufficient cooling of the produce during transport. The load should be covered with a white/light-coloured canvas to avoid overheating and to allow adequate air circulation throughout the produce.

A truck-ventilating device, can be used to facilitate airflow in non-refrigerated trucks consists of wind catchers and ducts, which are constructed using wooden crates or galvanized iron. The open-ended crates are wired together into a sturdy pattern. Air flows upwards through the load during transport, so avoiding extensive overheating of the produce. Best results can be obtained if produce is transported during the early morning hours before sunrise.

ii. Refrigerated trailers

Refrigerated vehicles/trailers must be properly insulated, have a high-capacity refrigeration unit and fan and an air-delivery duct. The vehicle should be well insulated to maintain a cool environment for pre-cooled commodities and adequately ventilated to allow air movement through the produce.

i. **Containers**

Containers are insulated metal boxes that are designed for the transport of large volumes of produce over long distances. They are generally equipped with thermometers and/or data loggers, which measure discharge air temperature at their specific locations and provide performance records of the operation of the refrigeration unit.

iv. Refrigerated containers

Refrigerated or reefer containers are generally equipped with a cooling unit, and require an external source of electricity to power the cooling unit and air circulation fans. Reefer containers are available in both 6.1-m and 12.2-m lengths. The 6.1 cm reefer container is the most commonly used in the fruit export industry worldwide. The 12.2 cm container is generally considered a relatively expensive option when compared to the 40-foot container.

Modern containers incorporate microprocessors and computers for controlling the refrigeration system. The 40-foot standard container can usually accommodate 20 ISO (International Organization of Standardization) pallets, while the 20-footer can accommodate nine pallets.

v. Porthole containers

Porthole containers are insulated containers in which cold air is supplied by an external cooler at the required temperature. The warm air within the porthole container is extracted from the top of the load. Air flows to and from the porthole container via vents or portholes.

vi. Controlled atmosphere (CA) containers

Controlled atmosphere containers are designed to maintain the composition of the storage atmosphere around fruits within the container

Categories of CA containers:

• Refrigerated – here the containers are fitted with special equipment to maintain controlled atmosphere (CA) conditions.

• Add-on – here containers have the basic controls fitted in the refrigeration unit, but require the addition of gas and chemicals to establish and maintain CA conditions.

• Central system containers – these containers have basic fittings that need to be connected to a central plant on board the ship to establish and maintain CA conditions.

vii. Break bulk refrigerated vessels

Break bulk refrigerated vessels consist of a number of cold rooms, which can accommodate palletized produce. Between 140 and 400 pallets per cold room can be accommodated in break bulk refrigerated vessels.

viii. Palletization

The palletization of produce facilitates handling during shipping. Palletization reduces damage to produce and increases the efficiency of loading and unloading operations. Plastic netting of palletized loads helps in preventing vibration and impact damage to the produce during transit.

3.5 Handling at wholesale and retail market

Wholesale and retail markets have been increasingly using automated ripening in which the gas composition of the ripening atmosphere, the room temperature and the fruit colour are continuously monitored and modulated to meet desired ripening characteristics. Improved ripening systems will lead to greater use of ripening technology to deliver products that are ripened to the ideal eating stage. Better refrigerated display units, with improved temperature and RH monitoring and control systems are being used in the retail markets especially for fresh cut fruits and vegetables. Many retail and food service operators are using Hazard Analysis Critical Control Points (HACCP) programs to assure consumers that the food products are safe.

4.0 Conclusion

Improvements are continually being made in attaining and maintaining the optimal environmental conditions (temperature, RH and concentrations of O_2, CO_2 and C_2H_4) in transport vehicles. Produce is commonly cooled before loading and is loaded with an air space between the palletized produce and the walls of the transport vehicles to improve temperature maintenance. In some cases vehicle and produce temperatures data are transmitted by satellite to control centre, allowing all the shipments to be continuously monitored. Some new trucks have air ride suspension, which eliminate vibration damage. As the industry realizes the importance of air ride, its popularity will increase.

5.0 Summary

Equipment used for the transport of fresh produce includes Refrigerated and non-refrigerated vehicles **–** for highway transport .Refrigerated and non-refrigerated vehicles
Refrigerated or non-refrigerated vehicles can be used for the bulk transportation of fresh produce. on-refrigerated vehicles must provide sufficient cooling of the produce during transport. The load should be covered with a white/light-coloured canvas to avoid overheating and to allow adequate air circulation throughout the produce. Refrigerated vehicles/trailers must be properly insulated, have a high-capacity refrigeration unit and fan and an air-delivery duct. The vehicle should be well insulated to maintain a cool environment for pre-cooled commodities and adequately ventilated to allow air movement through the produce.

6.0 Tutor Marked Assessment (TMA)

i. List the four types of mechanical damage that occur during transportation

ii. Describe the factors that contribute to overheating in a vehicle transporting crop produce
iii. Explain how overheating can be avoided in a vehicle transporting fresh produce
iv. List the equipment used in transportation of fresh produce.

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MODULE 3: TRADITIONAL AND MODERN METHODS CROP PROCESSING AND STORAGE

UNIT 1: PRINCIPLES OF CROP PROCESSING

UNIT 2: MODERN METHODS OF CROP PROCESSING

UNIT 3: TRADITIONAL FOOD PROCESSING TECHNOLOGY IN WEST AFRICA

UNIT 4: CALLENGES OF CROP PROCESSING

UNIT 5: MODERN METHODS OF CROP STORAGE

UNIT 6: TRADITONAL METHODS OF CROP STORAGE

UNIT 1: CROP PRODUCE PROCESSING

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1.0 Introduction

Agricultural processing may be defined as an activity, which is performed to maintain or improve the quality or to change the form or characteristics of the agricultural product. Processing operations are undertaken to add value to agricultural materials after their production. The main purpose of agricultural processing is to minimize the qualitative and quantitative deterioration of the material after harvest. High post-harvest food losses, arising largely from limited food preservation capacity, are a major factor constraining food and nutrition security in the developing countries of West Africa, where seasonal food shortages and nutritional deficiency diseases are still a major concern. Simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises that are crucial to rural development in West Africa. It is estimated that about 50% of perishable food commodities including fruits, vegetables, roots and tubers and about 30% of food grains including maize, sorghum, millet, rice and cowpeas are lost after harvest in West Africa. Ineffective or inappropriate food processing technologies, careless harvesting and inefficient post-harvest handling practices, bad roads, moribund rail systems, bad market practices and inadequate or complete lack of storage facilities, packing houses and market infrastructures are some of the factors responsible for high post-harvest food losses in West African countries.

2.0 Objectives

By the end of this unit you should be able to:

- Define food processing
- Describe the basic principles of agricultural processing
- Describe the different types of agricultural processing
- Describe sector wise food processing

1.0 What is Food Processing

Food processing is the change of transformation of plaint, animal or any other material used for food to improve its acceptability and ensure availability of such material all the year round.

Food processing includes food preparation (which makes food item ready for immediate consumption) and food preservation (which preserves food item for future use). Food processing may sometimes cause certain desirable food qualities to be lost e.g. tasks.

3.1 Reasons for Food Processing

a) To improve its digestibility, making it easier for the body to break down the food while it is in the stomach.
b) To improve its sanitary quality, making it safer to eat by killing harmful micro-organism.
c) To create desirable flavours which are pleasant to the taste.
d) To preserve it, so allowing it to be kept over a period saving time and energy.

3.2 Principles of Agricultural Processing

Food preservation may target to either the short or long term. Short term preservation may be applicable to horticultural commodities that are consumed relatively soon after harvest. For them the best preservation techniques involves keeping the product alive and respiring. Shorter preservation does not involve destruction of microorganisms or enzymes, deteriorative reactions will therefore proceed, often at a faster rate due to the stresses imparted during harvesting and handling operations. Long term preservations encompass inactivation or control of microorganisms and enzymes and reduction or elimination of chemical reactions that causes food deterioration. Microorganism may be controlled through the use of heat, cold, dehydration, acid, sugar, salt, smoke, atmospheric composition and radiations. Mild heat treatments in the range of 82oc to 93oc are commonly used to kill bacteria in low acid food but to ensure spore destruction; temperatures of 121oc wet heat for 15 minutes or longer are required. Refrigeration and freezing slow microbial growth and may kill a small fraction of microorganisms present in or on a fruit or vegetable, but they do not kill all bacteria. If all of the water in a product exists in a solid state, growth of microorganisms will be prevented, but growth would resume at the same or perhaps at an even more rapid rate when thawed. Dehydration serves to remove water required for growth from microbial cells and preserve horticultural crops against microbial deterioration. In a similar fashion, sugar and salts act as preservatives because they cause osmotic dehydration of microbial cells and eventual death. Control of moisture or RH of the storage environment is an important consideration in terms of desired maintenance of horticultural crop life and undesired preservation of microorganisms.

Food processing includes food preparation (which makes food item ready for immediate consumption) and food preservation (which preserves food item for future use). Food processing may sometimes cause certain desirable food qualities to be lost e.g. tasks

3.3 Methods used in the Preparation and Processing of Foods

i) By separation and sub-division
ii) By combination or mixing
iii) By heating
iv) By cooing
v) By the use of chemical compounds
vi) By the use of micro-organisms.

3.3.1 Separation and Sub – Division

Separation and subdivision facilitate or increase food palatability or eating quality. Separation involves the removal of undesirable part of the food material which may be distasteful coarse in texture and unattractive in appearance. For instance, peeling of cassava removes the outer layer which is unpalatable, coarse and unattractive as food. Paring of yams removes the coarse and less attractive cortex. Sub – division on the other hand, is the removal of part(s) of a food material which may cause fast deterioration of such food through spoilage.

3.3.1.1Methods used in separation and sub-division

a) Cutting – refers to the reduction of food material(s) into small pieces using a knife, matchet or cutlass.

b) Grinding – cutting food materials (e.g. tomato and pepper) into small pieces or a mash, with the aid of a wooden ladle or a mash stick in a mash bowl, or with a grinding stone set, machines could also be used.

c) Pounding – refers to the reduction of food into coarse or rough pieces or into a smooth mash or paste using a wooden mortar and pestle (e.g. fufu pounding). Blenches also serve similar purposes.

d) Grating – is the rubbing of food materials on a rough surface (usually holed metallic material) e.g. cassava or coconut grating.

e) Peeling – is the stripping or pulling off of the outer layer of a fruit or vegetable (e.g. banana, cassava or orange). A times, scalding with hot water, steam or a chemical solution may be used to remove the very thin skin on foods (e.g. tomatoes).

f) Paring – refers to the removal of the surface layers of food material (e.g. yams, cocoyam, and potatoes) with the aid of a knife. Scraping in the other hand is the removal of the surface layer of a food material by the application of pressure from a knife edge rather than cutting (e.g. scraping fish scales).

g) Cracking – is the letting of a hard kernel or nut with a stone or iron rod to remove the monocarp (e.g. palm kernel, coconut, or cashew)

h) Milling – is the crushing and sifting of grains into flour using a machine.

i).Other methods of separation and subdivision include filtering floatation pressing, refining, skimming, steeping, evaporation and centrifugation.

3.3.1 Combination or Mixing

This method is used to mix food materials or food ingredients or caused to be combined during food preparation in order to improve the palatability of the end product. This methods also ensures that food texture and flavor can be controlled.

3.3.2.1 Methods used in Food Combination or Mixing

i) Beating – mixing materials by briskly lifting and dropping with an appropriate tool. Beating (or whipping) is a rapid beating with a wire whisk, a fork or mechanical beater. It allows air into the food (e.g. when cowpea mash or eggs are whipped to cause the material to become light and fluffy).

ii) Stirring - refers to mixing materials with an appropriate tool such as spoon by a circular motion (e.g. stirring of porridge while cooking).

iii) Blending – mixing two or more ingredients thoroughly (e.g. mixing of corn dough, ground pepper or onions into mashed ripe plantain to make plantain doughnuts)
iv) Stir – pressing – is the pressing and turning of thickened starchy paste with a flat wooden stick, bit by bit, in a circular motion, to prevent lumping while cooking (e.g. during tuwo preparation).
v) Kneading – refers to the manipulation of food material (tuwo) and liquid by alternating pressure in folding and stretching (e.g. bread dough kneading).
vi) Cutting – is the incorporation of semi – solid fat into flour and other sifted dry ingredients with a knife to produce a coarse division of the fat, as in the preparation of pastry mixture.
vii) Folding – the mixing of materials with an appropriate tool used in a careful lifting and dropping motion (e.g. the folding of ingredients into whipped cowpea in the making of akra or bean nuts.
viii) Other methods include creaming, marinating and emulsification.

3.3.3Heating as a Preparation and Processing method

All substances contain heat, the intensity depends on the environmental condition prevalent around them. If the food substance is surrounded or is in direct contact with a heat source higher than itself, it absorbs more heat than it is given out. This causes the temperature of the substance to rise and vice versa. Heat is used in food preparation for cooking or toasting. Cooking refers to a situation where the entire food mass is affected by heating process at the same time (e.g. soap cooking or yam boiling) Toasting refers to when the heat primarily affects the surface of the substance (e.g. plantain toasting, or roasting or grilling over a direct heat_. Heating of any food substance results in complex changes in the food. These changes are dependent upon various factors:-
a) The method or the way by which heat is transferred to the food.
b) The length of time heat is applied to the food.
c) The temperature reached at the surface and within the centre of the food.
d) The type of food being heated.
The methods of cooking may be differentiated depending on the media through which the heat is transferred to the food. These include:
i) Air

ii) Water

iii) Sand

iv) Fat

v) A combination of two or more of these processing of cereals.

3.4 Types of Agricultural Processing

Agricultural processing may be defined as an activity, which is performed to maintain or improve the quality or to change the form or characteristics of the agricultural product. Processing operations are undertaken to add value to agricultural materials after their production. The main purpose of agricultural processing is to minimize the qualitative and quantitative deterioration of the material after harvest.

Different types of food processing can be categorized into:

Primary processing

Purification of raw materials by removing foreign matter, immature grain and then making the raw material eligible for processing by grading in different lots or conversion of raw material into the form suitable for secondary processing.

Secondary processing

Processing of primary processed raw material into product which is suitable for food uses or consumption after cooking, roasting, frying etc.

Tertiary processing

Conversion of secondary processed material into ready to eat form. Food items are marketed in different forms as raw, primary processed, secondary processed and tertiary processed. The farmers in general prefer to sell their agricultural produce immediately after harvest leaving a part for own consumption and seed purposes. The food processing sector has gained importance due to consumer’s preferences for ready to cook (RTC) and ready to eat (RTE) foods, besides increased demand for snack foods and beverages.

3.5 Sector wise Food Processing

Food processing is the set of methods and techniques used to transform raw ingredients into food or to transform food into other forms for consumption by humans or animals either in the home or by the food processing industry. Food processing typically takes clean, harvested crops or slaughtered and butchered animal products and uses these to produce attractive, marketable and often long shelf-life food products. Similar processes are used to produce animal feed.

3.5.1 Fruits and vegetable processing

The processed products from fruits and vegetables are beverages, jams, jellies, candies, preserves, canned fruits and vegetables, dehydrated fruits and vegetables, pickles, soup mixes, sauces and ketchups. Processing of fruits and vegetables involves a series of processes which include pre-coloring washing, grading, treating, storage, dehydration, peeling, slicing, crushing, extraction, bleaching, sterilizing, filling, scaling and sealing of containers.

People generally prefer fresh fruits and vegetables in Nigeria due to abundance of seasonal fruits throughout the year available at low price. However, in the recent years, processed foods in the form of canned fruits such as pineapple, mango slices and pulps, grapes, apple, peaches etc have increased considerably. The uses of fruits in the form of concentrated juice, dry powder, jam and jelly have also increased.

a. **Gari** processing cottage industries that processed raw cassava in to garri

b. **Rice milling:** The modern rice mills have separate processing mechanism for dehusking and polishing of the paddy. The husk can be utilized for energy and for industrial products like furfural and the bran for extraction of edible and non edible grades oil. These mills also have better recovery and lower energy consumption compared to conventional hullers.

c. **Wheat milling:** At present flours made by the roller mills are sold to bakers and confectionery company etc Sale of soy blended and branded wheat flour is likely to increase due to better quality flour and thus scope of organized wheat milling will increase in future.

d. **Pulse milling:** Pulses are the major sources for protein for the vegetarians.

e. **Oil extraction:** Oil extraction has been a cottage level activity in the country through the numerous oil mills. The introduction of high capacity mechanical expellers and solvent extraction technology has brought in modernization. Small capacity oil expellers have been introduced which could be installed in rural areas for promoting agric - business and that might provide more employment. Soybean is not only a good source of oil but also rich in protein. Soymilk analogues, nuggets and soy - blends are now marketed

f. **Processing of commercial crops**: Sugarcane, rubber, cocoa, oil palm, tea and coffee are major commercial crops grown in Nigeria and a processed into variety of products

g. **Packed and convenience food:** Modern packed and convenience foods such as bread, biscuit, confectionery, chocolates, ready to eat foods like noodles, cereal flakes, etc have become popular in recent years especially in urban areas although traditional foods have been used in the country in the form of roasted, puffed, sweet meat and baked products.

1.0 Conclusion

Agricultural processing may be defined as an activity, which is performed to maintain or improve the quality or to change the form or characteristics of the agricultural product. Processing operations are undertaken to add value to agricultural materials after their production. The main purpose of agricultural processing is to minimize the qualitative and quantitative deterioration of the material after harvest.

5.0 Summary

Purification of raw materials by removing foreign matter, immature grain and then making the raw material eligible for processing by grading in different lots or conversion of raw material into the form suitable for secondary processing. Food items are marketed in different forms as raw, primary processed, secondary processed and tertiary processed. The farmers in general prefer to sell their agricultural produce immediately after harvest leaving a part for own consumption and seed purposes. The food processing sector has gained importance due to consumers preferences for ready to cook (RTC) and ready to eat (RTE) foods, besides increased demand for snack foods and beverages.

6.0 Tutor Marked Assessment

i. Describe primary, secondary and tertiary of food processing
ii. Explain the principles of agricultural processing
iii. List three reasons for processing food
iv. What are the different methods used in processing foods.

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UNIT 2: METHODS OF PROCESSING CROP PRODUCTS

1.0 Introduction

2.0Objectives

3.0 Methods of processing crop products

3.1Cereals

3.1.1 Whole Meal Cereal

3.1.2 Decorticated Meal

3.1.2 De-germinated Meal

3.1.3 Polished Cereal

3.1.4 Industrial Processing of Cereal Grains

3.2 Processing of Roots and Tubers

3.2.1 Cassava

3.2.2 Yam

3.2.2.1 Production of Instant Yam Flour

3.3 Production of Fruit Juices

3.3.1 Orange/Grape-fruit Processing

3.3.2 Oil fruits

3.3.3 Oil seeds

4.0 Conclusion

5.0 Summary

6.0 Tutor Marked Assignment

7.0 References

1.0 Introduction

The common element in all sectors of the food processing is conversion of raw material into a product of higher value. In some situations, processing is a one-step conversion of raw material to a consumer product. The history of food processing lay emphasis on the role of establishing and maintaining microbial safety in foods, as well as the desire to establish and maintain economic shelf-life for foods. Processing methods are used worldwide as they improve the digestibility and nutritional quality of the grains.

2.0 Objectives

At the end of this unit you should be able to:

- Describe the methods of processing cereals
- Describe the methods of processing cassava
- Describe the methods of processing yam
- Describe the methods of processing oil fruits
- Describe the methods of processing oil seeds

3.0 Methods of Processing Crop Products

Ineffective or inappropriate food processing technologies, careless harvesting and inefficient post-harvest handling practices, bad roads, moribund rail systems, bad market practices and inadequate or complete lack of storage facilities, packing houses and market infrastructures are some of the factors responsible for high post-harvest food losses in West African countries.

3.1 Cereals

Cereals can be separated or subdivided into their components during processing into other forms of foods or industrial uses. The cereal grain may be de-husked (hulling) to remove the outer coat or hull of cereal grains in order to obtain the endorsperm. De-hulling separates the bran or seed chart and the germ. After de-hulling, the grain may be rolled (i.e. grinding of grain into smaller particles).This increases the digestion of the grain and makes it possible to use the product in various ways. Usually, cereal grains are processed in the dry form to make other products. Some cereal grains may be prepared as whole cereal meal, de-corticated or production is geared

towards the production of whole-wheat flours, employing a simplified process flow sheet, but most demand and effort is directed towards the production of white flour.
White flour is the ultimate product of flour milling. The aim of white flour milling is to extract a maximum amount of endosperm from the wheat berry in as pure a form as possible. The outer bran layers become the co-product of the process called wheat feed. Many operations also separate the embryonic part of the berry, known as the germ. This is a high value co-product when a market exists. Where a market for germ does not exist, it is sold for animal feed with the wheat feed produced. These co-products contribute significantly to the financial viability of milling operations. One of the keys to the success of a flour milling operation is the efficient, economical separation of starchy endosperm from the rest of the berry. The process has developed along very specific lines towards achieving this goal.

There is just one accepted manner in which flour is produced globally. This is known as the gradual reduction system. The gradual reduction system of flour milling is the process of taking the whole wheat berry and, via a series of grinding and sieving stages, producing white flour of the desired quality and yield. The gradual reduction system has enabled the production of flours of low ash content and high yield. Specialist, high quality flours, is produced by extracting high purity sub-products from within the process. There are three principal divisions within the process. These are known as the breaking system, the purification system and the reduction system. The purification system is not favoured by many millers and may be absent from processes. It is often replaced by what is known as the Sizing system. However, the other two blocks are present in all gradual reduction flour mills in operation today. The breaking block or break system is the area of the process where most endosperm separation is achieved. This work is performed principally on roller mills whose surfaces have a saw tooth profile. The rollers run at different speeds towards each other.

3.1.1 Whole Meal Cereal

This is obtained by grinding the cereal whole. The meal produced is not passed through a sieve to remove any parts of the grain such as the hull or the germ particles meals produced this way are 97 – 100 percent extraction and is known as a Whole meal". The name of the product reflects the cereal grain type used in producing it e.g. “whole maize meal”, “whole Wheat Meal” for meals produced from maize and wheat respectively.

If the cereal is coarsely ground, the product is known as “cereal grits”, and if finely ground, the product is called cereal flour. The particle size of cereal meal is between cereal grinds and cereal flour. Maize or sorghum “rice” or produced by milling either maize or sorghum to rice sized particles. This product is used in the same way as rice different process extraction rates may be use but the higher the extraction rate, the higher the nutrient component of the product.

3.1.1 Decorticated Meal

This is cereal meal which is also referred to as bolted meal or flour depending on the particles size. It is obtained by grinding the whole cereal into a fine meal which is passed through a sieve to remove portions of the full, leaving most of the germ in the meal. Some of the germ is taken out during the sieving to remove the hull giving the product 90 – 96% extraction rate.

3.1.2 De-germinated

This is a highly refined cereal meal produced by grinding whole grain cereal into fine flour. Most of the hull and the germ is removed by passing the flour through different sizes of mesh sieve. The meal of flour produced is 85% or less extraction, depending on the rate at which the hall and the germ have been removed from the final flour product. Coarsely mulled cereal grain cleaned of bran or hull and germ is called “de-germed grits”. The germ or the embryo portion of the cereal which is recovered during milling is called “cereal germ”. This is very rich in oil. Corn or maize oil is extracted from corn germ using organic solvents. The oil is recovered by distilling off the solvent, cleaned and refined. The residues left over after oil extraction is rich in protein and is used in animal feed formulations. The hull or the outer coating of the cereal which is removed during milling is known as “cereal bran”. During milling, the cereal brain obtained is attached to parts of the endosperm. Cereal bran may be added to cereal porridges or to cereal pastes. Cereal bran provides roughage which keeps the bowls free and therefore eliminates constipation

3.1.1 Polished Cereal

This is produced when the hull and the layer underlying it are removed (together with the germ) during the dry milling of whole grains (e.g. "polished rice").

The appearance of the remaining meal of flour is considered attractive or more appealing to consumers even though it is less nourishing. However, the processing used renders the products more stable when stored.

3.1.3 Industrial Processing of Cereal Grains

Industries cereal grains (e.g. wheat) are separated into portions of different qualities by a series of crushing, pulverizing and sifting processes which separate fractions of differing fineness. The grain is cleaned, before milling and moistened or conditioned (to cause the seed coat or the bran to absorb moisture and to toughen). It is then fed through a series of corrugated rollers placed far enough apart to crush the kernels into coarse fragments and largely separates the seed coat from the endosperm. This process is known as "breaking". At each crushing, some of the endosperm becomes sufficiently ground to pass through flour sieves as "break flour". The coarse particles of endosperm left behind are called "middling". These are small enough to pass through sieves that remove most of the bran. Some bran particles, small enough to go through with the middling are removed by air currents, a process called "purification". Middling may be bagged and sold as "farina" for use as breakfast cereal in creamed cereal porridge, or sold as "semolina" used in macaroni production

3.2 Processing of Roots and Tubers

These foodstuffs are packed or pared to remove the outer skin and cut into large or small pieces or sliced. Yams, sweet potatoes Irish potatoes, cocoyam all darken when their cut surface are exposed to the air. The darkening (or browning affect) is caused by enzymes acting on compounds in the raw food tissue in the presence of oxygen. The action of these enzymes may be checked by preventing the cut surface from coming into contact with air (oxygen). Water, weak salt solutions, sugar solutions or an acid solution in the form of diluted lemon or lure juice, vinegar or other fruit juice (e.g. pineapple juice) may all be used to cover cut pieces to prevent their surfaces from coming into contact with the air. Acid solutions are very effective; when the acidity is increased, the rate of darkening is decreased.

Another way of preventing contact with the oxygen in the air is by covering the cut surface with a compound or agent which reacts with or attracts oxygen. This makes the oxygen unavailable to the cut surface and hence the discolouring does not occur. These compounds known as reducing agents (e.g. sulphur dioxide and ascorbic acid) are used industrially to prevent darkening in roots and tubers, also in fruits and vegetables during processing.

3.2.1 Cassava

A great diversity of processing techniques has developed in different regions. Some of the processes are used in all areas either because they are standard methods for preparing starchy food, such as boiling or roasting or because they were introduced with the cassava when it was introduced from South America.

- The simplest techniques used to prepare cassava for immediate consumption are boiling, roasting or baking. Peeled roots are boiled whole or sliced and served in a variety of ways
- Roasting the roots is less popular with the Amerindians than boiling and generally only resorted to when no cooking utensils are available. Roots are roasted by placing them whole in the ashes of a fire
- Frying is believed not to have been used traditionally but to have been introduced by European. slices of peeled root are fried in oils of various kinds according to availability and taste
- In Vanuatu grated cassava is wrapped in banana leaves and baked in an oven
- The more complex technique involving pounding of the cassava roots into a paste is particularly popular on the African continent where it is a very widespread method, The resulting paste from all these crops is generally known in West Africa as fufu, also foofoo, fuifai, foufou, foutou and vou-vou depending on the locality.
- Fufu can be prepared by boiling or steaming peeled cassava roots and then pounding them in a wooden pestle and mortar until a homogeneous paste is obtained which is eaten with soups or stews of meat or fish
- The simplest method used and probably the most widespread certainly in Africa or Asia, for preparing flour from cassava is by sun-drying slices or chips of peeled roots which can then be stored as dried chips and ground into a flour when needed

- A method for extending the storage life of chips to up to 12 months and also speeding up the drying process is by parboiling them before drying, a technique often used in India and West Africa
- Amongst the most important products from Cassava roots are the coarse meals known as gari in West Africa

3.2.2 Yam

Yam, possibly the oldest cultivated food plant in West Africa, is of major importance to the economy of the sub-region that accounts for the bulk of world production of the crop. By far the most important product derived from white yam (*Dioscorea rotundata* Poir) **is fufu or pounded** yam, popular throughout West Africa. Traditionally, pounded yam is prepared by boiling peeled yam pieces and pounding using a wooden mortar and pestle until a somewhat glutinous dough is obtained.

3.2.2.1 Production of Instant Yam Flour

Arising from the need to have a convenience food and reduce the drudgery associated with the preparation of pounded yam, various brands of instant yam flour are now available in West Africa since the introduction of “poundo yam”, which is no longer in the market, by Cadbury Nigeria Ltd in the 1970s. Instant yam, on addition of hot water and stirring, reconstitutes into dough with smooth consistency similar to pounded yam. The product is so popular that considerable quantities are exported to other parts of the world, especially Europe and North America, where there are sizable African populations. Commonly, instant yam flour is produced by sulfiting peeled yam pieces, followed by steaming, drying, milling and packaging in polyethylene bags. Instant yam flour can also be produced by drum drying cooked, mashed yam and milling the resultant flakes into a powder using a process similar to that used for production of dehydrated mashed potato.

3.2 Production of Fruit Juices

Fruits are normally eaten fresh when mature but for long preservation and wider distribution, they are processed into juice. The few fruits that can be processed into juice are pineapple, mango, guava, citrus fruits, etc

3.3.1 Orange/Grape-fruit Processing

Fruits are sorted by hand to remove rotten, broken, diseased fruits. The sorted fruits are washed and may be de-oiled by passing the washed fruits through another metal column consisting of a series of revolving graters which rasp the thin skin layer under jets of water. The oil/water emulsion is then collected, screened and centrifuged to recover the oils. The juice is extracted by pressing; and screened to obtain a cleaner juice. Granulated sugar may be added if necessary. The juice is pasteurized, filled into sterilized cans, closed, cooled and dried for packing and storage.

Stored commodity includes crop produce/products, dried and smoked fish, meat, tides and skins, tuber products and household goods e.g. clothes, carpets, books etc. Crop produce obtained from field and horticultural crops are grouped into four classes:- durables, semi-durables, perishables and others.

3.3.2 Oil fruits

Since the oil palm gives the economically most important tropical oil fruit, the technologies for its extraction can serve as an example in this category. In the traditional process, the fruit is first removed from the bunches, generally after the bunches have fermented for a few days. The fruit is then cooked and pounded or trampled. The mashed mass is mixed into water. The oil and oil containing cell material is separated from the fibre and the nuts by rinsing with excess water and pressing by hand. The oil-containing mass, now floating on the top, is collected and boiled. In this step, the oil separates from the rest and collects on the surface. It is skimmed off and finally dried. The actual execution of the process may vary somewhat from area to area; most traditional processes, however, have in common the superfluous use of water. Using this process, generally not more than 50% of the oil is obtained.

The problems are:

- the digestion by means of pounding or trampling,
- the separation of the oil and oil containing material from the fibres and the nuts by means of water and the liberation of the oil by cooking afterwards.

The potential for improvement of this technology and thereby the development of small scale extraction equipment in principal depends on

- better cooking by means of steam,
- better digesting using a reheating step with steam and
- effective pressing in a batch press or continuously working screw press.

The modern process of extracting palm oil, used on a larger scale, starts with the steam sterilization of the bunches. The bunches are threshed and the fruit is digested mechanically, while heated with steam. The mass is then pressed in hydraulic presses or continuously in screw presses. The oil is separated from the press fluid by heating and is finally dried.

3.3.3 Oil seeds

In addition to the distinction made between traditional and modern methods, the processes for oil seeds should also be divided into so-called wet and dry extraction methods. Of the traditional wet processes, the extraction of coconut oil from fresh coconuts is the best known. It starts with grating the meat, after which the oil as well as the proteins and impurities are extracted as milk from the fibrous residue by pressing (by hand or foot) and rinsing with fresh water. The milk is left to stand to form an oil rich cream on top. The cream is boiled to separate the oil from water and other impurities. The oil can be skimmed off. It still contains a protein- rich residue that can be filtered off after drying and used for human consumption. Other oil seeds, like groundnuts, palm kernels and Shea nuts are roasted and crushed as fine as possible (e.g. first by pounding, followed by crushing between stones or a stone and an iron bar). The crushed mass is mixed with water, and the oil is obtained by cooking the mixture, causing the oil to float. The oil is finally skimmed off and dried by heating. Shea nut oil is often obtained by beating air into a mixture of crushed seeds with some water using a hand-operated butter making process. The milk or cream floating on top of the beaten mass at the end of the process is then cooked to evaporate the water and dry the oil. The weak points of these processes are the grating or crushing steps. They are time consuming and exhausting work, yet crushing is generally not fine enough. Thorough crushing can improve the oil recovery considerably. In many areas, engine-driven disc mills are used by women in small commercial enterprises to get their seed crushed.

4.0 Conclusion

Ineffective or inappropriate food processing technologies, careless harvesting and inefficient post-harvest handling practices, bad roads, moribund rail systems, bad market practices and inadequate or complete lack of storage facilities, packing houses and market infrastructures are some of the factors responsible for high post-harvest food losses in West African countries.

5.0 Summary

The common element in all sectors of the food processing is conversion of raw material into a product of higher value. In some situations, processing is a one-step conversion of raw material to a consumer product. The history of food processing lay emphasis on the role of establishing and maintaining microbial safety in foods, as well as the desire to establish and maintain economic shelf-life for foods. Processing methods are used worldwide as they improve the digestibility and nutritional quality of the grains.

6.0 Tutor Marked Assessment (TMA)

- Describe processing of cassava

- Describe processing of yam

- Describe the production of instant yam flour

- Explain processing of oil seeds

- Differentiate between decorticated and de-germinated meal

7.0 References and further Readings

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UNIT 3: Traditional Methods of Food Processing

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1.0 Introduction

Simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises that are crucial to rural development in West Africa. By generating employment opportunities in the rural areas, small scale food industries reduce rural-urban migration and the associated social problems. They are vital to reducing post-harvest food losses and increasing food availability. Regrettably, rapid growth and development of small-scale food industries in West Africa are hampered by adoption of inefficient and inappropriate technologies, poor management, inadequate working capital, and limited access to banks and other financial institutions, high interest rates and low profit margins. While a lot still needs to be done, some successes have been achieved in upgrading traditional West African food processing technologies including the mechanization of gari (fermented cassava meal) processing, the production of instant yam flour or flakes, the production of soy-ogi (a protein-enriched complementary food), the industrial production of dadawa (a fermented condiment

3 Objectives

At the end of this unit, you should be able to;

- Describe traditional food processing in west Africa and Nigeria
- Describe traditional food fermentation
- Explain the traditional method of flour production
- Understand the processing of fruits and vegetables in Nigeria
- Describe traditional boiling of roots and tubers

3.0 Traditional food processing technology in West Africa

The capacity to preserve food is directly related to the level of technological development and the slow progress in upgrading traditional food processing and preservation techniques in West Africa contributes to food and nutrition insecurity in the sub-region. Traditional technologies of food processing and preservation date back thousands of years and, unlike the electronics and other modern high technology industries, they long preceded any scientific understanding of their inherent nature and consequences. Traditional foods and traditional food processing techniques form part of the culture of the people. Traditional food processing activities constitute a vital body of indigenous knowledge handed down from parent to child over several generations. Unfortunately, this vital body of indigenous knowledge is often undervalued. Regrettably, some of the traditional food products and food processing practices of West Africa have undoubtedly been lost over the years and the sub-region is the poorer for it. Those that the sub-region is fortunate to retain today have not only survived the test of time but are more appropriate to the level of technological development and the social and economic conditions of

West African countries. Indeed, simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises in West Africa and their contributions to the economy are enormous. The objectives and main features of some of these traditional food processing techniques are presented in Table 1.5

Table 5.1 Objectives and main features of traditional West African food processing techniques

Technique/operations	**objectives**	**Mean features/limitations**
1. **Preliminary/postharvest operations:** threshing	To detach grain kernels from the panicle.	Carried out by trampling on the grain or beating it with sticks. Labour-intensive, inefficient, low capacity.
Winnowing	To separate the chaff from the grain.	Done by throwing the grain into the air. Labour intensive, low capacity, inefficient.
Dehulling	To remove the grain from its outer protective casing	Carried out by pounding the grain in a mortar with pestle. Labour-intensive, low capacity excessive grain breakage.
Peeling	To separate the peel or skin from the edible pulp.	Manual peeling with knives or similar objects. Labour-intensive, low capacity, loss of edible tissue.
2. Milling (e.g. corn)		
Dry milling	To separate the bran and germ from endosperm	Carried out by pounding in a mortar with pestle or grinding with stone. Laborious, inefficient, limited capacity.
Wet milling	To recover mainly starch in the production of	Carried out by pounding or grinding after steeping. Laborious, limited

	fermented foods e.g. ogi.	capacity, high protein losses, poor quality product.
3. Heat processing		
Roasting	To impart desirable sensory qualities, enhance palatability, reduce anti-nutritional factors.	Peanuts are roasted by stirring in hot sand in a flat-bottom frying pot over a hot flame. Laborious, limited capacity.
Cooking (e.g. wara)	To contract curd and facilitate whey expulsion, reduce microbial load, inactivate vegetable rennet, impart desirable sensory qualities.	Loose curd pieces are cooked in a pot over wood fire. Limited capacity.
Parboiling (e.g. rice)	To facilitate milling and enrich milled rice with B-vitamins and minerals.	Done by steeping paddy rice in cold or warm water followed by steaming in bags in drums. Limited capacity, poor quality product.
Blanching	To inactivate plant enzymes and minimize oxidative changes leading to deterioration in sensory and nutritional qualities, e.g. enzymatic browning.	Slices (e.g. yam for elubo production) are heated in hot water in a pot for various durations. Limited capacity, poor quality product.
4. Drying		
Shallow layer sun drying	To reduce moisture content and extend shelf life.	Product is spread in a thin layer in the open (roadside, rooftop, packed earth etc.). Labour intensive, requires considerable space, moisture too high for long-term stability, poor quality.

Smoke drying (e.g. banda)	To impart desirable sensory qualities, reduce moisture content and extend shelf life.	Meat chunks after boiling are exposed to smoke in earthen kiln or drum. Limited capacity, poor quality product.
5. Fermentation	To extend shelf life, inhibit spoilage and pathogenic microorganisms, impart desirable sensory qualities, improve nutritional value or digestibility.	Natural fermentation with microbial flora selection by means of substrate composition and back-slopping. Limited capacity, variable quality.

Source: International Union of Food Science & Technology (2008)

3.1 Traditional Fermentation

Fermentation is one of the oldest and most important traditional food processing and preservation techniques. Food fermentations involve the use of microorganisms and enzymes for the production of foods with distinct quality attributes that are quite different from the original agricultural raw material. The conversion of cassava (*Manihot esculenta, Crantz* syn. *Manihot utilissima* Pohl) to gari illustrates the importance of traditional fermentations. Cassava is native to South America but was introduced to West Africa in the late 16th century where it is now an important staple in Nigeria, Ghana, Ivory Coast, Sierra Leone, Liberia, Guinea, Senegal and Cameroon. Nigeria is one of the leading producers of cassava in the world with an annual production of 35-40 million metric tons. Over 40 varieties of cassava are grown in Nigeria and cassava is the most important dietary staple in the country accounting for over 20% of all food crops consumed in Nigeria. Cassava tubers are rich in starch (20-30%) and, with the possible exception of sugar cane, cassava is considered the highest producer of carbohydrates among crop plants. Despite its vast potential, the presence of two cyanogenic glucosides, linamarin (accounting for 93%of the total content) and lotaustralin or methyl linamarin, that on hydrolysis by the enzyme linamarase release toxic HCN, is the most important problem limiting cassava utilization. Generally cassava contains 10-500 mg HCN/kg of root depending on the variety, although much higher levels, exceeding 1000 mg HCN/kg, may be present in unusual cases. Cassava varieties are frequently described as sweet or bitter. Sweet cassava varieties are low in cyanogens with most of the cyanogens present in the peels. Bitter cassava varieties are high in cyanogens that tend to be evenly distributed throughout the roots. Environmental (soil, moisture, temperature) and other factors also influence the cyanide content of cassava. Low rainfall or drought increases cyanide levels in cassava roots due to water stress on the plant. Apart from acute toxicity that may result in death, consumption of sub-lethal doses of cyanide from cassava products over long periods of time results in chronic cyanide toxicity that increases the prevalence of goiter and cretinism in iodine-deficient areas.

CASSAVA ROOTS

(306 mg HCN/kg)

↓

PEELING HCN

(184 mg HCN/kg)→ HCN

↓

WASHING

↓

GRATING

↓

FERMENTING

↓

PRESSING HCN

(52 mg HCN/kg) → HCN

↓

SIFTING

↓

ROASTING HCN → HCN

↓

SIEVING

↓

GARI

(10 mg HCN/kg)

Figure 1: Process flow chart for gari production

Symptoms of cyanide poisoning from consumption of cassava with high levels of cyanogens include vomiting, stomach pains, dizziness, headache, weakness and diarrhea. Chronic cyanide toxicity is also associated with several pathological conditions including konzo, an irreversible paralysis of the legs reported in eastern, central and southern Africa, and tropical ataxic neuropathy, reported in West Africa, characterized by lesions of the skin, mucous membranes, optic and auditory nerves, spinal cord and peripheral nerves and other symptoms.

Without the benefits of modern science, a process for detoxifying cassava roots by converting potentially toxic roots into gari was developed, presumably empirically, in West Africa. The process involves fermenting cassava pulp from peeled, grated roots in cloth bags and after dewatering, the mash is sifted and fried.

During fermentation, endogenous linamarase present in cassava roots hydrolyze linamarin and lotaustralin releasing HCN. Crushing of the tubers exposes the cyanogens which are located in the cell vacuole to the enzyme which is located on the outer cell membrane, facilitating their hydrolysis. Most of the cyanide in cassava tubers is eliminated during the peeling, pressing and frying operations (Figure 1). Processing cassava roots into gari is the most effective traditional means of reducing cyanide content to a safe level by WHO standards of 10 ppm, and is more effective than heap fermentation and sun drying, commonly used in eastern and southern Africa. Apart from 'gari' there is a vast array of traditional fermented foods produced in Nigeria and other West African countries. These include staple foods such as fufu, lafun and ogi; condiments such as iru (dawadawa), ogiri (ogili) and ugba (ukpaka); alcoholic beverages such as burukutu (pito or otika), shekete and agadagidi; and the traditional fermented milks and cheese. Lactic acid bacteria and yeasts are responsible for most of these fermentations. The fermentation processes for these products constitute a vital body of indigenous knowledge used for food preservation, acquired by observations and experience, and passed on from generation to generation.

3.1.1 Dadawa Fermentation

Dadawa or iru is the most important food condiment in Nigeria and many countries of West andCentral Africa (21). It is made by fermenting the seeds of the African locust bean. The seeds are rich infat (39-47%) and protein (31-40%) and dadawa contributes significantly to the intake of energy, protein and vitamins, especially riboflavin, in many countries of West and Central Africa. For the production of dadawa, African locust bean seeds are first boiled for 12-15 hr or until they are tender. This is followed by dehulling by gentle pounding in a mortar or by rubbing the seeds between

the palms or trampling under foot. Sand or other abrasive agents may be added to facilitate dehulling. The dehulled seeds are boiled for 30 min to 2 hr, molded into small balls and wrapped in banana leaves. A softening agent called ‘kuru’ containing sunflower seed and trona or ‘kaun’ (sodium sesquicarbonate) may be added during this second boiling to aid softening of the cotyledons. The seed balls are then covered with additional banana leaves or placed in raffia mats and allowed to ferment for 2-3 days covered with jute bags. Alternatively, the dehulled seeds, after boiling, are spread hot on wide calabash trays in layers of about 10 cm deep, wrapped with jute bags and allowed to ferment for about 36 hrs. The fermented product is salted, molded into various shapes and dried. The main microorganisms involved in dadawa fermentation are *Bacillus subtilis* and *Bacilluslicheniformis* and one of the most important biochemical changes that occurs during fermentation is the extensive hydrolysis of the proteins of the African locust bean. Other biochemical changes that occur during dadawa fermentation include the hydrolysis of indigestible oligosaccharides present in African locust bean, notably stachyose and raffinose, to simple sugars by α- and β-galactosidases, the synthesis of B-vitamins (thiamin and riboflavin) and the reduction of anti-nutritional factors (oxalate and phytate) and vitamin C. An improved process for industrial production of dadawa involves dehulling African locust bean with a burr (disc) mill, cooking in a pressure retort

for 1 hr, inoculating with Bacillus subtilis starter culture, drying the fermented beans and milling into a powder. Cadbury Nigeria Plc in 1991 introduced cubed dawadawa but the product failed to make the desired market impact and was withdrawn. It would appear that consumers preferred the granular product to the cubed product.

Importance of fermentation

- Apart from detoxification by the elimination of naturally-occurring nutritional stress factors, other benefits of traditional fermentations include reduction of mycotoxins such as aflatoxins as in ogi processing
- the conversion of otherwise inedible plant items such as African locust bean (*Parkiabiglobosa* Jacq) and African oil bean (*Pentaclethra macrophylla* Benth) to foods, i.e. iru and ugba respectively, by extensive hydrolysis of their indigestible components by microbial enzymes.
- Fermentation improves the flavor and texture of raw agricultural produce, imparting a desirable sour taste to many foods, such as gari and ogi, and leading to the production of distinct flavor components characteristic of many fermented foods.
- Fermentation may lead to significant improvement in the nutritional quality of foods by increasing the digestibility of proteins through hydrolysis of proteins to amino acids, increasing bio-availability of minerals such as calcium, phosphorus, zinc and iron through hydrolysis of complexing agents such as phytate and oxalate, and increasing nutrient levels, especially B-vitamins, through microbial synthesis.

3.2Production of Complementary Foods

It is generally agreed that breast milk is adequate both in quantity and quality to meet the nutrient and energy requirements of the infant up to the age of four to six months. Beyond this period, complementary or weaning foods are required to supplement the mother’s breast milk. The weaning period is the most critical in the life of infants and preschool children, with serious consequences for growth, resistance to diseases, intellectual development and survival if the child’s nutritional needs are not met. Unfortunately, in West Africa and other parts of Africa, traditional complementary foods are made from cereals, starchy roots and tubers that provide mainly carbohydrates and low quality protein. These complementary foods exemplified by ogi are the leading cause of protein-energy malnutrition in infants and preschool children in Africa.

African infants experience a slower growth rate and weight gain during the weaning period than during breastfeeding due primarily to the poor nutritional qualities of traditional African complementary foods such as ogi. Apart from their poor nutritional qualities, traditional African cereal-based gruels used as complementary foods have high hot paste viscosity and require considerable dilution before feeding; a factor that further reduces energy and nutrient density. Although nutritious and safe complementary foods produced by food multinationals are available in West African countries, they are far too expensive for most families. The economic situation in these countries necessitates the adoption of simple, inexpensive processing techniques that result in quality improvement and that can be carried out at household and community levels for the production of nutritious, safe and affordable complementary foods.

3.3 Complementary Foods from Cereal-Legume Blends

As cereals are generally low in protein and are limiting in some essential amino acids, notably lysine and tryptophan, supplementation of cereals with locally available legumes that are high in protein and lysine, although often limiting in sulfur amino acids, increases protein content of cereal-legume blends and their protein quality through mutual complementation of their individual amino acids. This principle has been utilized in the production of high protein-energy complementary foods from locally available cereals and legumes. Community-based weaning food production using 4:1 ratio of locally available cereals and legumes have proved successful in many African countries. ‘Weanimix’, a weaning food made from a cereal-legume blend, developed by the Nutrition Division of the Ministry of Health in Ghana was introduced on a large scale in the country in 1981. To promote the production of weaning foods from locally available cereals and legumes at the household level, grinding mills were provided to rural women groups in Ghana with UNICEF assistance. Although legume supplementation increases protein content and protein quality of cereal-legume blends, the types of cereal and legume involved as well as the blending ratios are critical. Increasing legume concentration in the blend generally increases the protein score until a new limiting amino acid is
imposed. Using a blend quality prediction procedure based on the amino acid scores of mixtures of cereals and legumes, the relative performance of maize, millet and sorghum supplemented with cowpea, groundnut, pigeon pea, soybean and winged bean in various weaning formulations has been estimated. Mixtures of cereals with groundnut produced the poorest quality blends due

to the relative inadequacy of groundnut protein in complementing cereal amino acids. Soybean and winged bean produced the best quality blends with cereals, followed by cowpea and pigeon pea in that order.

3.4 Production of Instant Yam Flour

Yam, possibly the oldest cultivated food plant in West Africa, is of major importance to the economy of the sub-region that accounts for the bulk of world production of the crop. By far the most important product derived from white yam (*Dioscorea rotundata* Poir) is fufu or pounded yam, popular throughout West Africa. Traditionally, pounded yam is prepared by boiling peeled yam pieces and pounding using a wooden mortar and pestle until a somewhat glutinous dough is obtained. Arising from the need to have a convenience food and reduce the drudgery associated with the preparation of pounded yam, various brands of instant yam flour are now available in West Africa since the introduction of “poundo yam”, which is no longer in the market, by Cadbury Nigeria Ltd in the 1970s. Instant yam, on addition of hot water and stirring, reconstitutes into dough with smooth consistency similar to pounded yam. The product is so popular that considerable quantities are exported to other parts of the world, especially Europe and North America, where there are sizable African populations.

Commonly, instant yam flour is produced by sulfiting peeled yam pieces, followed by steaming, drying, milling and packaging in polyethylene bags. Instant yam flour can also be produced by drumdrying cooked, mashed yam and milling the resultant flakes into a powder using a process similar tothat used for production of dehydrated mashed potato.

Table 2.2.5 Some Ttraditional Nigerian Fermented Foods

Fermented food	Raw materials	Microorganism involved	Uses
Gari	Cassava pulp	*Leuconostoc* spp. *Lactobacillus* spp. *Streptococcus* spp. *Geotrichum candidum*	Main Meal
Fufu	Whole cassava roots	*Lactobacillus* spp. *Leuconostoc* spp.	Main meal
Lafun	Cassava chips	*Leuconostoc* spp. *Lactobacillus* spp. *Corynebacterium* spp. *Candida tropicalis*	Main meal
Ogi	Maize, sorghum and	*Lactobacillus*	Breakfast

	millet	*plantarum* *Streptococcus lactis* *Saccharomyces cerevisiae* *Rodotorula* spp. *Candida mycoderma* *Debaryomyces hansenii*	cereal, weaning food
Iru (Dawadawa)	African locust bean (*Parkia biglobosa)* Soya bean	*Bacillus subtilis* *B. licheniformis*	Condiment
Ogiri (Ogili)	Melon seed (*Citrullus vulgaris*), Fluted pumpkin (*Telfairia occidentalis*), Castor oil seed (*Ricinus communis*)	*Bacillus* spp. *Escherichia* spp. *Pediococcus* spp.	Condiment
Kpaye	*Prosopsis africana* (algarroba or mesquite	*Bacillus subtilis* *Bacillus licheniformis* *Bacillus pumilus*	Condiment
Ugba (Ukpaka)	African oil bean (*Pentaclethra macrophylla*)	*Bacillus licheniformis* *Micrococcus* spp. *Staphylococcus* spp.	Delicacy usually consumed with stock fish or dried fish
Palm wine	Palm sap	*Saccharomyces* spp. Lactic acid bacteria Acetic acid bacteria	Alcoholic drink
Burukutu/Pito/Otika	Sorghum Millet &maize	*Saccharomyces* spp. Lactic acid bacteria	Alcoholic drink
Shekete	Maize	*Saccharomyces* spp.	Alcoholic drink
Agadagidi	Plantain	*Saccharomyces* spp.	Alcoholic drink

3.5 Traditional method of Flour Production

Traditionally, cereal grains are processed either in the dry or wet form to make various products. Maize, sorghum, rice and wheat are de-hulled first by pounding and then by winnowing. The crushed grain is then ground on large grinding stones to produce dry flour. Whole grain is sometimes moistened before grinding to produce whole grain flour. This process is tedious and time consuming and recovery rate is about 50 to 60% which is very low. The product obtained contains about 30% moisture making it to be unstable. The instability of the flour is improved by repeated pounding. Soaked cereal grains may also be ground into meals which are mixed with water to form dough whole cereal meals produced by grinding are not passed through a sieve to remove any part of the cereal. They are 100% extracts.

Brown Flours

These are produced by just drying the cereal grains, which are then roasted and ground into brown flours with a pleasant flavor. These flours are used in making breakfast porridges, cooked paste products, in soups as thickening agents in plantain products or as beverages by mixing in ginger solution with sugar added.

3.6Traditional Boiling of Roots and Tubers

In traditional food preparation, sweet cassava, cocoyam, sweet potato and yam are wasted, peeled and covered with cold water for boiling-either alone or in combinations seasonings are added to enrich its palatability and flavour.

3.6.1Fufu Processing

Boiled roots and tubers are pounded in a shallow wooden mortar with a fufu stick or a wooden pestle to produce a paste commonly call "fufu". In order to produce good quality fufu, the cut roots or tubers are cooked until they are "just done", with the starch granules partially gelatinized over cooking causes too much gelatinization and the product does not form fufu. The pieces are crushed, little by little, with the fufu pestle. This prevents lumpiness in the finished product. The crushing continues until all pieces are completely crushed before the actual pounding begins. The pounding mass is moistened with some cold water and is turned over by hand between beatings. The beating causes the starch granules to break down and imbibe water causing the mass to become soft, sticky and elastic. At the desired level of stickiness and softness, the product is shaped into forms and served with thin or thick soups.

Fufu is either made with one type of root or tuber such as cassava, yam, or cocoyam or is made in combination. Sweet potato is never used to make fufu, since it is too sweet and does not become sticky or elastic when pounded.

3.6.2 Preparation of Fried and Roasted Roots and Tuber Snacks

Pared yam, cocoyam and potatoes are cut up, salted and deep fat fried to make fried products. The snacks are sold as ready-to-eat or convenience foods. The curt pieces are also grilled or roasted on an open fire as ready-to-eat foods. Cocoyam, irish potato and green plantain can also be thinly sliced, fried in oil and salted to make crisps which are packaged and sealed in plastic bags as snacks. Note that yams are not usually used for crisps because they become bitter when fried to crispiness.

3.6.3Processing of Cassava into Gari

The commercial and traditional methods of processing cassava into gari are guided by the same basic principles. The fresh tuber is peeled, washed and grated to produce pulp. The pulp is then collected and packed in a hessian bag. This bag is pressed down either mechanically or in traditional form by use of stones or other heavy materials for about 3 days during this process, moisture is lost and some hydrogen cyanide or prussic acid is eliminated. Also a fermentation process eats in with the liberation of more hydrogen cyanide.

Two stages of fermentation reaction are identified in grated cassava mash. The first stage involves the attack of starch granules by some cassava bacteria which produce acids, causing a reaction with the poisonous compounds to form gases which are liberated within 24 hours of fomentation. The second stage occurs when sufficient organic acids including lactic acid have been produced in the mash. Fermentation by yeasts then occurs to form compounds which give the characteristics taste and flavor to fermented cassava dough products, especially the aroma in gari or fermented roasted cassava meal.

The pulp is sifted to remove the coarse fibres and leave the starch or gari which is later heat – dried (“fried”) with constant stirring. Any hydrogen cyanide left behind is virtually destroyed. To produce the yellow type of gari, a little palm oil is added during “frying” to give the characteristic colour. The finished product (gari) has a swelling capacity of about three times its weight when cold water is added. In the dried form it can store for some time.

3.7Processing of Fruits and Vegetables in Nigeria

Nigeria is richly endowed with a wide range of indigenous fruits and vegetables which play important roles in nutrition and healthy body development. They are also available sources of raw materials for growing Agro-allied industries. Due to inadequate nutritional education, limited utilization potentials, seasonal variability, the perishable nature of the foods, inadequate preservation methods, and the consumption habits of the people, the great potentials of these foods have not been realized. The result is under exploitation and wasting away of the abundant fruits and vegetables in all ecological zones of the country.

Fruits are classified as the fleshy edible products of a woody or perennial plant which are closely associated with flower (e.g. mango, pineapple, guava, banana, avocado pear, apple, grape, citrus, plantain, passion fruits Saturn/sweet sops, etc). Vegetables on the other hand are the shrubs or herbaceous annual or which may be the leaves, shrubs, roots, flowers, seeds, fruits or inflorescence of the plant. In Nigeria, most of the commonly used vegetables are the leaves, seeds fruits and roots which are the succulent plants parts catch as supplementary foods, side dishes (raw) or as soup with condiments along with other main staple dishes (e.g. spinach, lettuce, cabbage, cauliflower, pumpkin, bitter leaf, *amaranthus*, onions, tomatoes, okra, pepper, melons, garlic, peas etc).

Fruits and vegetables are perishable food and so require some form of processing for longer storage. The processing of fruits and vegetable has been carried out in almost every home in the country but the storage life of most of the processed foods does not offer encouragement for commercial exploitation.

There are very few factors like Lafia Canning Factory in Oyo State and the Vegetable and Fruit Processing Company Ltd in Borno State that operate exclusively on fruit and vegetable processing in Nigeria. Other cottage industries like Takog Food Processing Company and Tella Fruit Juice Industries both at Ibadan, Oyo State, that process fruits and vegetables on a small scale for limited circulation. The vegru company in Bauchi process fruit into juices and tomatoes into puree. The two major firms marketing fruit squashes, Lever Brother Nigeria Ltd and the Nigeria Bottling Company Ltd, produce entirely from imported concentrates.

There are several methods used in processing fruits and vegetables to facilitate their storage with a longer shelf life. This makes them available during out-of-season periods. These methods include dehydration, canning, processing with sugar, fermentation and picking.

3.7.1 Dehydration

Fruits and vegetables are having tissues with cellulose wall which is semi-permeable. The cellulose wall is killed by either heating or freezing which allows the food material to lose water but retaining the nutrients in them. The deliberate removal of water from food products before marketing is referred to as "dehydration" drying or evaporation. After the removal of water, the products remains in a liquid or fluid state, and this is termed "evaporation". When the end product is in solid form, the material is said to have been "dried" or "dehydrated".

The primary objective in removing water from any food material is to reduce its bulk, so that it can be economically handled, transported, and distributed.

The objective is to improve its keeping quality by reducing the moisture level. Fruits and vegetables have high moisture content and are highly perishable. If moisture is removed, these food materials can be preserved over a long period with minimal microbial attack.

Fruits and vegetables are heat-sensitive and therefore present special problems when drying. Dehydration has to be carried out under carefully controlled conditions. Prolonged heat treatment results in a loss of flavor, a decrease in nutritional quality, vitamin losses, and a marked decline in the acceptability of the product. Successful dehydration therefore involved minimal heat treatment as well as careful handling.

When properly done, drying can preserve taste, concentrate flavors and protect nutritive values. Drying is inexpensive, in energy terms and dried products are also economical in their storage requirements. A combination of warmth, low R Humidity and moving air will dry any product. Dry air circulating around moist food collects some of the moisture from the food. With an air flow to carry away the moisture-laden air while allowing dry air in, the drying continues until equilibrium or a balance is reached. Although heat is needed for drying, a low R H. and air movement are more important. Too low temperature and or too high R. H may cause prolonged drying period which may result in food spoilage. Conversely, a high temperature with a low humidity cause "case hardening" (a situation when the outside layer of the food fries very quickly and hardens, so locking moisture into the product and casing spoilage problems).

3.7.2 Preparing Fruits and Vegetables for Drying

Fruits and vegetables to be dried must of top quality. Duping will preserve most of the original flavor but will not improve food quality. Fruits and vegetables are thoroughly washed preferably in cold water. Cold water helps to preserve freshness soaking fruits and vegetables in water is not recommended, since vitamins are leached out. The food absorbs moisture, which makes drying more difficult. The washed produce is trimmed, peeled if necessary and cut up into pieces.

Food to be dried is cut into various shapes, helves, cubes, slices and strips. The thinner and smaller the pieces, the quicker they dry. It is necessary that they are as uniformly cut as possible to allow for uniform drying and retaining the nutrients in them. The deliberate removal of water from food products before marketing is referred to as "dehydration" drying or evaporation. After the removal of water, the products remain in a liquid or fluid state, and this is termed "evaporation". When the end product is in solid form, the material is said to have been "dried" or "dehydrated".

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3.7.3 Mango Processing

Ripe mature mango is most suitable for juice production. The fruits are peeled manually and collected into the crushing machine which grinds them into a very fine blend. A considerable amount of water is added to the blend in the container, thoroughly mixed and siphoned into a pre-heater which preheats it to 15 – 20^{o}C, then to the juice extractor which separates the pulp from the juice. The juice is then clarified to separate out sediments still present in the juice. The juice is pasteurized before filling into sterilized cans using automatic filling machine. The filled cans are conveyed through the conveyor belt to the automatic sewing machine after which they are immersed in boiling water for adequate time period (20 to 30 minutes) for complete sterilization. After sterilization, the cans are pre-cooled, cooled finally and packed.

3.7.4 Plantain processing

Plantain is processed into flour for longer preservation. The flour could be used for the production of baked goods like bread, cake and biscuit. Other food products which could be produced from plantain in a cottage industry are chips and dodo.

Plantain flour production is usually carried out as a means of preservation, price stability and for easy transportation to other parts of the country where plantain is not grown. Until recently, the production has been carried out on very small-scale by individual households who process into flour the surplus plantain fruits which could not be consumed or sold fresh. Plantain flour is produced by drying, milling and sieving to coffee beans, kola nuts, tobacco leaves etc.

Crop produce are subject to varying degrees of post harvest loss. Post harvest loss is defined as any change in the availability, edibility (where applicable), wholesomeness or quality of produce, produce that reduces its value to humans which dares, place during the period between maturity of the crop and the time of its final consumption or utilization.

4.0 Conclusion

The critical role that food science and technology plays in national development cannot be Overemphasized in West African countries where high post-harvest losses, arising largely from limited food preservation capacity, are a major factor constraining food and nutrition security. Seasonal food shortages and nutritional deficiency diseases are still a major concern. While the large food multinationals play a unique role in promoting industrial development in West Africa through employment generation, value-added processing and training of skilled manpower, their impact is felt greatest in the urban areas. Small-scale food industries that involve lower capital investment and that rely on traditional food processing technologies are crucial to rural development in West Africa. By generating employment opportunities in the rural areas, small scale food industries reduce rural urban migration and the associated social problems. They are vital to reducing post-harvest food losses and increasing food availability. While a lot still has to be done in upgrading traditional West African food processing technologies, some successes have been achieved including the mechanization of gari processing, the production of instant yam flour, the production of soy ogi, the industrial production of dadawa.

5.0 Summary

Traditional food processing activities constitute a vital body of indigenous knowledge handed down from parent to child over several generations. Unfortunately, this vital body of indigenous knowledge is often undervalued. Regrettably, some of the traditional food products and food processing practices of West Africa have undoubtedly been lost over the years and the sub-region is the poorer for it. Those that the sub-region is fortunate to retain today have not only survived the test of time but are more appropriate to the level of technological development and the social and economic conditions of West African countries. Indeed, simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises in West Africa and their contributions to the economy are enormous. Simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises in West Africa and their contributions to the economy are enormous. Traditional foods and traditional food processing techniques form part of the culture of the people. Traditional food processing activities constitute a vital body of indigenous knowledge handed down from parent to child over several generations. Unfortunately, this vital body of indigenous knowledge is often undervalued. Regrettably, some of the traditional food products and food processing practices of West Africa have undoubtedly been lost over the years and the sub-region is the poorer for it. Those that the sub-region is fortunate to retain today have not only survived the test of time and more appropriate to the level of technological development and the social and economic conditions of West African countries.

6.0 Tutor Marked Assessment (TMA)

- Explain traditional food fermentation in Nigeria
- Describe the processing of cassava into gari
- Differentiate between durable and semi- durable grain legumes
- Describe the tradition way of processing roots and tubers

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UNIT 4: Challenges of Crop Processing

Table of Contents

1.0 Introduction

Ineffective or inappropriate food processing technologies, careless harvesting and inefficient post-harvest handling practices, bad roads, moribund rail systems, bad market practices and inadequate or complete lack of storage facilities, packing houses and market infrastructures are some of the factors responsible for high post-harvest food losses in West African countries. Fermentation is one of the oldest and most important traditional food processing and preservation techniques.

2.0 Objectives

At the end of this unit, you should be able to:

- Describe the challenges of processing crop produce
- Describe the strategies for enhancing crop processing
- Understand the future post - harvest priorities

3.0 Challenges of processing crop produce

The foregoing discussions reveal that significant amounts of post-harvest losses affected the economy and welfare of farmers, consumers, and traders. Therefore, some of the important socio-economic and technological issues of post-harvest processing and preservation need to be considered to reduce post-harvest losses.

These include.

A) Size of land holding

The size of land holding has a significant effect on the extent of post-harvest losses at the farm and different handling points. A comparative study on of the various post-harvest practices among small, medium, and large farms would enable researchers and policy makers to identify the appropriate post-harvest loss reducing technologies for specific group of farmers.

B) Educational background and training of farmers and traders

The educational attainment of the farmer including his attendance in informal training related to postharvest technology is another factor that needs to be considered. Their participation in various seminars, workshops, and informal training on farming techniques would enable them to be receptive to the adoption of appropriate technology.

C) Attitude of farmers

Some investigations of the farmers' attitude disclosed that some of them are not aware of proper handling practices since they are more concerned with pre-harvest losses due to flood, drought, insect damage etc. Others view, loss or gain as the result of God's punishment or God's mercy; others associated loss to chance or bad luck etc.

***D)* Level of income of farmers**

Income is very important as it affects largely the level of capital investment of farms. The income generated from farm to off-farm sources would determine whether the farmer is financially capable of reducing post-harvest losses through investment on better packaging materials or storage facilities. Low investment has been argued as the main chain effect of low income. The lack of adequate capital inhibits farmers from buying recommended containers for transport. Most often, farmers may harvest immature crops mainly fruits and vegetables during times when they need immediate cash for the family and/or when prices are high. Harvesting of immature commodities result in poor quality products.

E) Presence of middlemen in marketing channel

In Nigeria middlemen are the common source of financing for small farmers. Usually the rate of interest in cash or kind is very high. A well-managed and organized cooperative is expected to reduce post-harvest losses compared with individual farmer operation.

F) Capital investment and financing

Capital investment of some middlemen like exporters, truckers, and cold storage owners is high because of high cost of buildings, vehicles, equipment and machinery and other related costs. A much higher capital investment is expected in the operation of cold storage facilities. The relationship between big capital investment and post-harvest losses, and information on postharvest practices should be collected through research.

G) Consumer's behaviour

The extent of post-harvest losses at the consumer level can be related to their educational level, income, taste and preference, attitude, and family size. It is expected that the higher the educational attainment of the consumer, the lesser will be the food losses or vice-versa. The relationship between these two variables needs to be empirically tested. A few studies show that household income appears to have a strong relationship between the choice of sorted and assorted food items specially fruits and vegetables. In Metropolitan area, high-income groups prefer to purchase sorted products for assurance of good quality and convenience in preparation. Low-income groups however, prefer assorted fruits and vegetables due to lower prices. The consumers have stronger preference for freshly harvested fruits and vegetables than stored ones. The tendency of some consumers to over purchase cheap but highly perishable fruits and vegetables has led to wastage due to inadequate storage facilities.

H) Role of mass media

Dissemination of post-harvest information through the mass media as a strategy to minimize losses at the consumer level, advertisements and promotion programs on post-harvest practices of food items should be carried-out to motivate proper attitudes towards reducing food losses.

I) Participation of policy makers

Participation of policy makers in the development of postharvest industry is essential, considering their capacity to create the required policy and climate conducive to adopting post-harvest practices. Thus, an intensive and more effective extension effort would be required by policy makers who set national priorities. Providing policy guidelines for increasing post-harvest research and development activities carried out by research institutions and universities to determine the best-suited technology at the farmer and grain processor levels is also needed.

3.1Strategies for enhancing crop processing

The future strategies of post-harvest research should be determined keeping the following constraints in view:

A) Climatic constraints at harvesting

Rainfall at harvest time delays harvesting, threshing and drying of cereals grains. The rainfall at this time favours disease and pest infestation as well as reduces seed quality. High temperature reduces yield and increases disease incidence. Rainfall and hailstorm in the later part of winter and during summer cause reduction in millet grain yield and quality.

B) **Harvesting, threshing, cleaning, and sorting**

Appropriate machines need to be developed and adopted through research and extension for harvesting, threshing, cleaning and sorting.

C) **Drying and field transportation systems**

The drying problem is acute, particularly when there is rainfall. It is a very serious problem in the eastern region of the country where the wet period is longer. The problem is more acutely felt in the case of grain legumes since they lose viability more rapidly at high humidity. Large quantities are further spoiled by fungal attack.

D) Storage

In spite of some research conducted on storage of food grains, legumes and oil seeds the most suitable storage technologies are yet to be developed. Development of home level techniques for drying and storage of various crops is required

E) **Handling and transportation**

Inadequate transport, lack of mechanical handling facilities, lack of mobile refrigeration facilities are some of the acute problems encountered during handling and transportation. Development of improved packaging technologies for fruits, vegetables, tubers and spices, and processed products is needed.

F) **Processing and preservation**

Utilization of fruits, vegetable and tuber crop wastes, extension of shelf life of fresh fruits, vegetables and spices, and home-level processing technologies should be promoted.

3.2 Future post-harvest research priorities

- Genetic manipulation for long life, diseases and environmental-stress resistant cultivars.
- Modeling cultivating conditions for high quality and long life (avoiding root stress by heat or drought).
- Environmental friendly pest control.
- Objective determination of suitable harvesting date.
- Postharvest treatments (heat, UV, irradiation CO_2, chemicals) for storage ability.
- Monitoring refrigerating systems
- Optimum storage conditions as storage for tropical fruits, ornamentals, planting material, fresh pack and lightly processed produce.
- Possibilities of modified atmosphere packaging (MAP), absorption layers, inserts sensors, PP films with micro pores
- Prevention of possible pathogenic organisms in MAP products.
- Adaptive control of storage conditions with biological sensors.
- Storage during transport and as quarantine measures.
- Humid forced air pre-cooling.
- Minimum impact and vibration norms for bruising during sorting and packaging.
- Objective non- destructive measuring of quality and maturity
- Environmental friendly packaging.
- Consumer and traders quality preferences in each country.
- Cost and return of the investment of postharvest technology.
- Cost and return of the investment of postharvest technologies.
- Fundamental research on senescence, ripening, respiration, ethylene effect, chilling, fermentation, superficial browning.

4.0 Conclusion

The post-harvest losses of different food items especially fruits and vegetables, are a great concern to us. Post-harvest losses due to inadequate facilities of processing and preservation must be given due importance to ensure the food security both at macro and micro levels. Short term preservation may be applicable to horticultural commodities that are consumed relatively soon after harvest. For them the best preservation techniques involves keeping the product alive and respiring. Shorter preservation does not involve destruction of microorganisms or enzymes, deteriorative reactions will therefore proceed, often at a faster rate due to the stresses imparted during harvesting and handling operations. Long term preservations encompass inactivation or control of microorganisms and enzymes and reduction or elimination of chemical reactions that causes food deterioration.

5.0 Summary

High post-harvest food losses, arising largely from limited food preservation capacity, are a major factor constraining food and nutrition security in the developing countries of West Africa, where seasonal food shortages and nutritional deficiency diseases are still a major concern. Simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises that are crucial to rural development in West Africa. It is estimated that about 50% of perishable food commodities including fruits, vegetables, roots and tubers and about 30% of food grains including maize, sorghum, millet, rice and cowpeas are lost after harvest in West Africa. Ineffective or inappropriate food processing technologies, careless harvesting and inefficient post-harvest handling practices, bad roads, moribund rail systems, bad market practices and inadequate or complete lack of storage facilities, packing houses and market infrastructures are some of the factors responsible for high post-harvest food losses in West African countries. Fermentation is one of the oldest and most important traditional food processing and preservation techniques.

6.0 Tutor Marked Assignment (TMA)

- Describe the principles of food processing
- Describe primary, secondary and tertiary processing of crop products

– Describe processing of cassava
– Describe processing of yam
– Describe the strategies to enhance postharvest research

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UNIT 5: Traditional Methods of Crop Storage

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1.0 Introduction

Normal storage is defined as the keeping of foodstuffs open to the atmosphere subject to room temperature and humidity. In the real sense, storage of foodstuffs begins immediately; the crop is detached or harvested from the parent plant. The decomposition caused by fungi, bacteria and nematodes starts in the field and continues during the cause of storage. Food self-insufficiency in Nigeria depends on increase production, reduced post- harvest losses, improved processing methods and improved product distribution. But how can increase in food production, improved processing methods, and improve product distribution be effective or possible if post- harvest losses are not to be studied and improved upon when the need arises.

2.0Objectives

In this unit, you should be able to:

- Describe the different traditional methods of food storage
- Explain the methods of storage of maize
- Describe the methods of storage of roots and tubers
- Explain the problems associated with indigenous traditional storage of roots and tubers
- Describe the improved storage methods of roots and tubers
- Describe the agents of deterioration of stored foods

3.0 Traditional Methods of Food Storage

More than three-quarters of the agricultural output of African smallholder farmers is kept at village level for local use and stored using traditional methods. Storage at the household level offers several advantages:

-It stores food close to the majority consumer

- It gives farmers easy access to their assets and facilitates sale transactions
- It does away with transport and handling costs and eliminates losses which occur at this level
- It serves as a source of information regarding the supply of grain on the market which informs production decisions.

If the household storage is still full when farming preparations are underway, this might signal that there is still an oversupply of the type of grain on the market. An informed farmer may reduce his acreage from the over supplied grain to another crop. The type of foodstuff and the size of the crop to be stored determine the design and capacity of these facilities. Farmers store their crops either outside, suspended or on platforms, or in granaries, or even inside their homes.

1) **Areal Storage**

Unshelled maize cobs and other un-threshed cereals are suspended in bunches or sheaves, using rope or plant material, under eaves, from the branches of trees or the top poles driven into the ground. The grain dries in the air and the sun until it is needed by the farmer for consumption or marketing. The disadvantage is that the grain is exposed to the environment and pests.

2) **Storage on the ground**

This is for temporary storage, following on immediately from harvesting and lasting only a few days, either because the farmer had not had time to bring in what he has harvested or because he wants to let it dry in this manner for a while when there is no prospect of rain. Storage on the ground is not efficient and not good in tropical areas because of the high incidence of damp. If a farmer uses this method the grain should be placed on a tarpaulin.

3) **Platforms**

A platform consists essentially of a number of relatively straight poles laid horizontally on a series of upright posts. If the platform is constructed inside a building, it may be raised just 35 - 40 cm above ground level to facilitate cleaning and inspection. Platforms in the open may be raised at least 1 meter above ground. Platforms are usually rectangular in shape, but circular or polygonal platforms are common in some countries. Grain is stored on platforms in heaps, in woven baskets or in bags. In humid countries fires may be lit under elevated platforms, to dry the produce and deter insects or other pests. Instead of being horizontal and flat, the platform may be conical in shape; conical platforms are pointed at the bottom and are up to 3 meters in diameter. Such platforms facilitate drying because of their funnel shape.

At the top they consist of a frame of horizontal poles which is square, circular or polygonal in shape, against which the timbers which form the cone rest. These timbers meet at the bottom on a wide central supporting post.

4) Cribs

A distinct improvement on platforms, a crib has ventilated sides made of bamboo grass stalks or even wire netting. It should face such a way that the prevailing winds blow perpendicular to the length. In humid countries where grain cannot be dried adequately prior to storage and needs to be kept well aerated during the storage period, traditional granaries (cribs) are usually constructed entirely out of plant materials. This includes timber, reeds and bamboo which provide good ventilation. Storage cribs made of wood and chicken-wire have been introduced by NGOs. These worked well in Rwanda and rural parts of Uganda but were rejected by farmers in Kenya because the sides made of chicken wire made the contents visible and were easy to steal from. One fault with the pictured crib is that the design does not include rat entry prevention measures.

5) Dwellings

Unthreshed cereals are commonly stored under the roof of dwellings, hanging from the roof timbers or spread out on a grid above the fire, the heat and smoke ensuring that the insects are deterred. These grain reserves are intended for day to day consumption because they are within easy reach and safe from theft and pests.

6) Mud granaries

These granaries are made of clay which is sometimes mixed with fragmented plant materials (grass, twigs). In some cases the clay comes from termite mounds. They may also be constructed with clay bricks. They are insulated from the ground by means of wooden poles, clay pedestals or large stones. They maybe either circular or rectangular in shape; in the latter case the inside may be partitioned off into separate compartments. In Senegal mud granaries 3 m by 1.50 m are found with a central corridor leading to slattes80cm above the ground. The paddy sheaves stored in them are dried by means of a fire which is kept burning in the corridor. In some regions, these granaries are covered with a straw roof or built completely of mud.

Some are more or less round with the tip pointing downwards and resting on stones. These mud granaries are common in Nigeria, Chad, Mali, Mauritania and Niger and are a cheap means of storage well suited to the dry climate of these countries. While some are quite small, others have a capacity of up to 5 tons. Because they can be hermetically sealed, insects are unable to penetrate and find it difficult to develop once inside because of reduced oxygen.

The complete lack of ventilation means moisture content of the grain must not exceed 10% and the humidity must be less than 70%. These granaries are not resistant to persistent or heavy rainfall and care must be taken to seal up promptly the cracks which easily form with this type of material.

3.1Traditional Maize Storage

Cribs

Traditionally, maize farmers use cribs of various types for storing their maize cobs in the sheath at the village level. These cribs have poor facilities for continuous drying of the maize, insect control and rodent control. An improved maize crib, has therefore been designed for use byfarmers for effective storage of maize at the Village level.

3.1.1 Construction of the Maize Crib

i. **The site for the Crib**: Your crib should be constructed on a level sit which is clear of trees and bushes. This enhances good ventilation c the maize in the crib and makes the maize dry quickly. If possible, is better to build your crib on a raised area of ground where there good breeze.

ii. **The Shape of the Crib**: Your crib should be rectangular in shape. The length can be of any measure depending on the quantity of maize you wish to store. The width should be narrow, from 90 cm in wetter areas to 150 cm in dry areas. In wetter areas of the forest zone, the 90 cm width should be used whereas, in the drier areas of the Western States, Delta State and the Eastern States, the wider crib may prove satisfactory. In most areas, a standard width of 120 cm. is usually recommendation. One ton of maize would require a 150cm long by 120 cm wide and 120 - 150 cm high crib storage space.

iii. **Orientation of the Crib**: The long side of your crib should face the direction of the prevailing wind. This enables the wind to blow through the mass of maize cobs more easily and allows efficient drying. Most rapid drying can be achieved in the 90 cm. wide crib and to enable free passage of air, the crib should never exceed 150 cm in width.

iv. **Construction of the Crib:** The crib is constructed in two basic parts

(a) The platform carrying the weight of the maize cobs and

(b) The frame-work which supports the sides and roof of the

Procedure

(i) Select the location, size and orientation of your crib and mark out the basic dimensions on the ground.

(ii) Poles to support the platform for the maize should be let into the ground to a depth of 3Cf- 40 cm. at points corresponding to the corners of the crib and at reasonable intervals along the length and middle of each end of the crib. The overall length of these poles should be 160 - 170 cm. so that, when let into the ground, they are able to support the platform at a height of not less than 120 cm. from the ground. The number of these poles you require will depend on the size and shape of your crib. Bamboo is recommended, where available.

(iii) Horizontal poles are fixed by nails or ropes to the top of platform supporting poles, first lengthwise along the outer edges of your platform and then across the width. You will now have a rigid platform to support your maize.

(iv) Two long poles of about 400 cm. length are let into the ground at the midpoint of each end of your crib. These will support your ridge pole. Depending on the length of the crib, additional centrally located ridge-supporting poles may be required.

(v) A series of vertical poles - 300 cm. long should then be erected corresponding to, and close to the poles supporting your platform frame. These poles will support the side of the maize compartment and, together with the ridge pole, the roof of the crib.

(vi) To stabilize the structure, a horizontal pole is lashed or nailed at each end of the crib to the top of the corner poles and to the ridge supporting poles, the ridge pole is fixed in position and further poles to support the outer edge of the roof are fixed horizontally along the outer top edges of the crib. You should now have a rigid upper framework for your crib.

(vii) A light framework of palm-leaf midrib or split bamboo can now be fixed from the ridge poles to the upper horizontal poles at the side of the crib and by weaving in further material in a lattice base for your crib roof is constructed.

(viii) The roof is made of grass (preferably - ekong grass), or raffia leaves which is knitted or woven in the traditional way and then fixed to the roof framework of the crib.

(ix) A retaining wall for your maize must now be constructed. This consists of horizontal poles nailed or lashed to the roof supporting poles up to the level to which the maize cobs are to be stored. You should, of course, leave a gap at one end of the crib for loading and access.

(x) From the inside of the crib – 2cm mesh chicken wire netting should be used to cover the walls and floor of the crib. This should be firmly fixed to the main framework of the crib. Alternatively, a palm midrib or split bamboo lattice may be used. This must be firmly secured to the main frame of the crib and made strong enough to support the weight of the maize cobs especially across the crib floor

(xi) If you have used bamboo for the vertical poles of your crib framework, you may not get a problem with rats attacking your maize, provided your platform is at least 120 cm. above ground level as rats are not easily able to climb the bamboo poles. Where you have used other poles for your crib frame, you must make rodent guards for all the 'legs' of your crib to prevent rats from getting to your maize.

Rodent guards are made from iron or aluminum sheet which is cut to shape so that when wrapped around the leg of the crib, a complete cone is formed. These rodent guards should be fixed at a height of from the ground with the open end of the cone facing down-wards. When in position, the outer edges of the cone should be about 12 cm. from the leg of the crib and no space should be left at the top end through which a rat may pass.

A further precaution is to keep the area around your crib clear. Rats can climb up plants growing close to, or farm implements etcetera, carelessly left leaning against your crib, and from there gain entry into your crib.

(xii) Variations in Materials*:* The description given above is for the basic structure of a crib which can be made entirely from local materials (except for the rat guards). It is possible to construct cribs of a more permanent kind using other materials, i.e. by using treated timbers for the framework and galvanized iron sheeting for the roof. Another type can be made entirely of iron.

3.1.2 Methods of Storage and Insect Control

1. After harvesting, the husk is removed from the maize ear leaving the cobs which will be at about 25% moisture content at this time.
2. The cobs are carried to the site of your crib in baskets or in bags and loaded into the crib for storage.
3. As each bag is emptied and spread in the crib, one of the insect control measures, described below is applied to the maize from that bag. In this way, you will get an even distribution of your insecticide
4. The application of Insecticide Dusts:
   (a) The application of Pirimiphos Methyl 2% dust for the protection of maize in cribs at a dosage rate of 10 ppm should be effective for 4 months. This dust is available from Chemical and Allied Products Nigeria (Ltd.) formerly ICI (Nigeria) Ltd. The procedure of application is detailed below. The quantity to be used per bag of maize would quarter fill a cigarette tin. Where scales or balances are available, the quantity required is 45 gmsper bag of maize.

   (i) Obtain a cigarette tin or any other tin of the same size.

   i. Perforate its closed end with a number of small holes.
   ii. Fill the tin up to ¾ full with (45 gm) of Pirimiphos Methyl dust and replace the lid.
   iii. Apply the contents of this tin evenly over the contents of one bag (produce bag) of maize after loading into the crib.
   iv. Repeat this procedure for each bag of maize loaded into the crib.
   v. Treat all the maize loaded into the crib bag by bag until the crib is full.
   vi. The maize should now be protected against heavy insect attack for about four months.
   vii. If further storage after four months is desired, further dust may be applied to the top and sides of the maize in the crib.

viii. Maize treated with insecticide should not be used for eating for about two months after application. After two months, it is considered that the treated maize is safe for consumption after normal processing.

(c) Pirimiphos methyl is also available as 2% emulsifiable concentrate called Actellicwhich is mixed with about 3 times its volume of water and used to spray the maize cobs evenly as they are loaded into the crib. This also protects the maize for 4 - 5 months. At intervals of about 3 months, the surface and outer cobs can be re-sprayed with liquid Actellic.

3.2 Traditional Storage of Roots and Tubers

Normal storage is defined as the keeping of foodstuffs open to the atmosphere subject to room temperature and humidity. In the real sense, storage of foodstuffs begins immediately; the crop is detached or harvested from the parent plant. The decomposition caused by fungi, bacteria and nematodes starts in the field and continues during the cause of storage.

Food self-insufficiency in Nigeria depends on increase production, reduced postharvest losses, improved processing methods and improved product distribution. But how can increase in food production, improved processing methods, and improve product distribution be effective or possible if postharvest losses are not to be studied and improved upon when the need arises.

3.2.1 Traditional Yam Storage

The food storage in the developing world is so severe, especially in the rural areas, that any means to increase agricultural production and limit losses is welcome. Traditional yam storage methods are designed within the framework of a self-sufficient economy and have ensured the subsistence of populations for generation. These traditional storage methods are based especially on the capacity of various yam varieties to resist rot. In this respect, the best species are *D. alata*and *D. dumetorum.*

According to the survey carried out in Benin on post- harvest technology, almost 85% of the rural population consumes yams that they produce themselves. Taking into account these new data, and observations, efforts which should be maintained and developed, are being made to reduce post- harvest losses.

Yams are stored in many different ways depending upon the customs and practices of the various tribes which grow them. Two of the main precautions followed in storing yams are keep them dry and away from the soil, and also protect them from rays of the sun.

After the yams have been harvested, all the soil clinging to the tubers is removed, as it encourages the yams to grow, they also may harbor diseases. The yams are then removed to the yam store. In some districts, it consist of a rough shed supported on strong corner posts and with the floor raised 2 or more feet above the ground and composed of rachis of palm-leaves, often referred to as branches. The wall of the shed are often made of the same material, and the roof is generally, consist of grass or palm-leaves or other form of thatch. The yams are piled on the floor and air is able to circulate freely through the gaps in the form and walls, which is great advantage in helping the yams to withstand deterioration. The main disadvantage of this system is that yams in storage is often begin to rot. Rotting is caused by fungi and is spread by contact so that the rot or mould quickly spreads from one yam to another as they piled close together in heaps. Also, each yam does not have equal conditions of drying and the yams at the bottom of the heap generally, have too much heat and hot air, and they contain more moisture, disease spreads more rapidly and through them. Moreover, they tend to sprout earlier and this is a distinct disadvantage when yams are kept for eating.

In the Calabar district, yams are harvested in September or October and hung up to dry for three months. The seed yams are then put into a sheltered place, such as a shed, and are covered with a layer of plantain or other leaves. The upper portion of the yams are placed facing upwards and in January sprouts generally appear. This system is specially adopted to help the yams to sprout, after which they are planted out at the end of January or February.

Probably, one of the best ways of storing yams is that followed by the Fantes, Northern Ashatis, and also by the Ibo tribes in the eastern.

A large frame work of poles is first erected, “living posts” being used for the vertical upright supports which are arranged in rows very close placed in position and tied to the erect poles with bush fire. The space left between each pair of erect poles with bush fire. The space left between each pair of erect poles is roughly 2 to 4 feet and 1 to 2 feet between the horizontal poles.

As the yams are brought in from the farm they are carefully, cleaned and all the soil removed, and they are then tied one by one to the erect poles beginning at the bottom. Long pieces of fibre are used, and they are looped round each yam and pulled tight so that each yam rests against the upright pole and often against the horizontal pole as well. The yams are generally, stung up on both sides of the upright pole in such a way that they are kept slightly apart. The great advantage of this system is that each tuber has practically the same amount of air and the same temperature, so that conditions of storage are much more even and satisfactory.

The double rows of poles are placed generally 5 or 6 feet apart so that a farmer with many yams store covering a considerable area, with rows or ranks of yams which he can walk between and inspect with the greatest of ease. Yams of the same variety are generally stored in the same part of the yam store so that one farmer may have five or six varieties of yams in separate groups in different parts of his store.

Another advantage of these stores is that the living poles quickly produce shoots at their upper ends and a mass of leaves soon completely shade the yams stored beneath, and the poles are not attacked by termites or boring insect. The shade from the sun also prevents the tubers from cracking, as easily happens when they are fully exposed to the sun's rays. Even in wet weather the yams easily dry up afterwards because of the diffused sunlight and the wind circulating freely through the cracks.

These yams stores are sometimes made near the farm or on the outskirts of the village, and are often surrounded by fence which is entered through special door. The stores are often constructed in the compound itself so that the yams can easily be reached and removed one by one, beginning from the top, and used as food. In Ibo districts, yams produced are kept in different parts of the compound, the men's yam being the larger.

After the yams have been stored for some weeks, and especially in damp weather, they begin to sprout. When stored in heaps, the yams at the bottom may have produced sprouts 2 to 3 feet long before they are discovered. In yam racks, however the sprouts can easily be seen, and the farmer goes round his store every few days, breaking off the sprouts with his fingers, or removing them with a knife.

3.2.2 Traditional Cassava Storage Methods

Cassava tubers are extremely perishable. They can be kept in the ground prior to harvesting for up to about 2 years, but once they have been harvested they begin to deteriorate within 40 to 48 hours. The deterioration is caused by physiological changes and subsequently, by rot decay. Mechanical damage during the harvesting and handling stages also renders the crop unsuited to long term storage.

Deterioration of cassava has an adverse effect on the product, and thus the crop must be stored properly. Traditional and modern methods of storage have been devised to combat post harvest losses.

In most areas where cassava is grown under subsistence farming conditions, the problem of storage is overcome by leaving the mature cassava crop in the ground until needed. The disadvantage of this method is that:

- Large area of land are use as storehouse for the already matured crop and therefore cannot be used for further crop and therefore cannot used for further crop, this increases the economic output of the land and increases preserve on the land (there is already a considerable amount of pressure on the land in many countries in Africa because of high population growth rates).
- Susceptibility to loss is increased because the tubers are vulnerable to attack by rodents, insects and nematodes.
- Tubers become more fibrous, lignifications occur, and consequently the crops starch content and its suitability for many food preparations decline.

Other traditional methods, based on the principle of prevention moisture loss from the tubers include:

1. Storing harvested tubers in pits involves buying them in pits lined with straw or some other vegetative materials.

2. Pilling them into heaps and watering them daily to keep them fresh.
3. Coating them with paste of mud.
4. Storing them under water.

These methods prolong the shelf life of cassava by only a few days and are not widely used.

3.2.3 Traditional Cocoyam Storage Methods

Cocoyam is usually harvested when the leaves begin to senesce (8-12 months after planting). In the regions where the rains do not immediately follow crop maturity, corms can be left in the soil and harvested as needed. Otherwise, the crop is completely harvested and any excess is stored.

Cocoyam intended for storage are harvested carefully to avoid injuring the corms and cormels which are exposed to sunlight for 2 to 3 days to encourage suberization. Tubers are stored in a dry, cool place either covered with dry leaves or in a hole lined with dry banana or plantain leaves. In some cases, wood ash is sprinkled over the tubers (probably to serve as a fumigant or pesticide). The heap is covered with dry soil to form a mound about 50cm above ground level. Under such conditions Cocoyam can keep up to 4 months. The major problem encountered during storage are rotting and sprouting.

In the middle-belt of Nigeria, fresh cocoyam when harvested is stored inside baskets for a while before they begin to rot. Fresh cocoyam is not usually palatable to insects or rodents, therefore, animals are not a major problem to fresh cocoyam storage.

Cocoyam unlike yam and cassava have less value as staple food in Nigeria and so not much is done to store them.

3.2.4 Traditional Storage of Sweet Potato

Of the four major root crops commonly grown in Nigeria, sweet potatoes are not given the best based on cultural reasons. In some parts of the country, sweet potato was considered as “dog food” and used only for feeding animals and most people do not like the taste (that is the sugar content). An increased awareness of the nutritional value of this crop has changed and situation, however, and sweet potato cultivation human consumption is expanding. The major obstacles to sweet potato storage in Nigeria are pests and sprouting. Traditionally, after harvest only sound tubers are stored. The tubers are exposed to sunlight for 2 to 3 days to suberize, they are then put in a dry place or in a basket that is kept in a dry place and covered with banana leaves or grasses. Tubers may also be put in a hole lined with dry leaves in a dry place. Wood ash is sprinkled on top of the tubers and the heap is covered with dry leaves or dry grass. In rare cases, a mound of dry earth is built on top of the heap. Under these conditions, the tubers keep up to 3 months, when the stored tubers are inspected, sprouted tubers are removed for consumptions and rotten tubers are discarded. During transportation of the tuber from the field to the market, it is stored in a sack and the mouth is covered by the leaves of the potato or grasses. This way it stays fresh for a longer time. At times, the soil clinging to the stain of the sweet potato is allowed to stay on it as the tubers go bad when the soils are removed from them.

3.2.5 Traditional storage of Irish Potato

This is the least produced tuber in the country. This is because of the special environmental conditions required for its cultivation. It requires a cool dry weather to thrive well. The best place where the highest yield has been attained so far is in Jos the capital of Plateau state.

The tuber has a delicate peel that can peel off especially during transportation to other parts of the country. So far, its storage has been difficult but farmers normally allow the tubers in the air to dry up, that is enough ventilation to reduce moisture content to the barest minimum. After this, they are packed into jute bags for transportation to distant places like the south and west. The tubers can also be stored by pouring ash on them and at the same time allowing air to move freely to touch each other as it generates heat and where there are not one, can easily be transferred to the next. The tubers are checked frequently to pick out the bad ones. The tubers are also stored in baskets covered with dry leaves. The basket will allow air into it and the temperature of the tubers reduced, thereby reducing the rate of respiration and its ability to store better.

3.3 Problems Associated with Indigenous Traditional Storage of Roots and Tubers

Losses appear at all stages from the field to the consumer's table. There are losses during harvest, transportation to the markets, and processing. At all these stages, losses are caused by various factors. They may be due to external agents (insects and other predators) or physical factors (handling, transportation and storage conditions) or they may have physical origins. All these are the problems of storage. The problems of traditional storage are described below:

1. Disease and Pest

Disease and pest greatly reduce yields of roots and tubers thus aiding deterioration in storage, for example, cassava has been adversely affected by some pests, e.g the cassava mealy bug (*Phenacclocus manihoti*) and green spider mite (*Mononychellus species*). Yams suffer from nematode, yam beetle, leaf spot and viral diseases. Similarly, Cocoyam are subject to attack by blight and the sweet potato yield declines under attack by viruses, root knot nematodes and the sweet weevil.

2. Labour Shortage

The shortage of labour is often accentuated by the seasonality of operations and division of labour is high coupled with a few that are available.

3. Post –harvest Technology

Roots and tubers, in addition to problems of harvesting are too bulky to transport and handle. Because of their perishability, they also have problems of storage. They have low protein content and must be processed, enhance their use in composite flours. The methods and equipment to ensure their availability in urban areas throughout the year.

4. Socio-economic Constraints

Roots and tubers suffer bias in research, extension, resource allocation, and even consumption and utilization because they are regarded as “poor people’s crops and of a lower status than cereal staples. For this reason, there are often shifts among higher income or urban classes toward cereals. In addition to such shifts, the availability of cereals in forms that are easier to store and handle enhances the demand for them and their products. Roots and tubers are only slightly involved in international and inter-regional trade and, therefore there is a limit to move them from surplus areas to areas of scarcity.

5. Prices

Problems of marketing include those of collection and handling of bulky small quantities of irregularly supplied producer of high water content and perishability passing through long marketing chain involving several intermediaries and varying periodic markets. The absence of an adequate marketing organization for roots and tubers makes farmers accept any price that is offered the farm gate or local market by middle men, who are able to process and transport goods to urban centers. Consequently, farmers receive only a small fraction of the final price. In many countries, there are policy constraints for producers of roots and tubers that result in prizes for cereals but not for roots and tubers, this happens because of the poor traditional ways of storing these crops.

3.3.1 Improved Storage Methods of Roots and Tubers

Among the improved storage methods for fresh cassava are those based on techniques involving freezing, gamma irradiation, control of storage environment (relative humidity and temperature) and waxing. However, none of these techniques has been sufficiently tested. Three improved storage methods which have undergone sufficient testing include:

- Dipping fresh tubers in fungicide and packing them in polyethylene bags.
- Storing in specially prepared trenches.
- Storing them in moist saw dust.

Although these three methods are not yet widely used, they are useful for small and medium-scale cassava production.

a. Storage in Polyethylene bags

This method appears to be the simplest way of storing tubers. If properly conducted, it ensures a shelf-life of two weeks or more. The method is based on the principle of “curing”. The capacity of tuber to form a new layer of cells over damaged tissues. Freshly, harvested roots are treated with 0.4% solution of mertect, a thiabendazole based fungicide. They are then packed in polyethylene bags and sealed. Inside the bags, the tubers create the necessary temperature/humidity environment (temperature should range between 30 and 40^0C and RH should exceed 80%. The fungicide treatment prevents the growth of microorganism in humid environment.

b. Storage in Trenches

These low-cost method, developed by the Nigerian stored products Research Institute keeps cassava fresh for at least 6 to 8 weeks and be implemented easily by farmers and processors. A trench is dug in the ground at a site which has a low water table, thus protecting the tubers from seepage of underground water. The trench should be 2m long, 1.5m wide and 1m deep. Depending on the size of the tubers, a trench of this size can store from s to 0.7 tons of cassava. .

3.4 Agents and Causes of Deterioration of Stored foods

Stored foods are affected by a number of biological agents which cause deterioration. These include:-

a) Micro- organisms (fungi, bacteria and yeasts)
b) Arthropods (insects and mites)
c) Rodents (rats and mice)

Those organisms can cause considerable damage to stored produce improvement in storage methods reduces losses of stored produce. However, storage pests may still gain access to stored commodities and cause economic damage, especially in the tropics where the storage structures are inadequate. The rate of spoilage of duce may be aggravated by other factors such as climatic, technical or economic consideration.

Many species of insects and mites are found in stored produce but a few actually cause economic damage and loss. Some of them may even be beneficial (e.g. predators and parasitoids) because they attack other arthropod pests. The two major insects pests groups are beetles and moths both of which are halometabolaus (i.e. they undergo complete metamorphosis in which the larval forms differ remarkably from the adult forms.

The non-biological causes of deterioration of stored commodities include:

a) Physical factors – temperature, humidity, water (moisture) and gas which influence the physiological activities of storage arthropod pests.

These are the conditions, methods and duration of storage, state of the product (whether broken or laden with impurities, residues etc)

b) Physical properties of commodities

These include; free moisture, specific heat and thermal conductivity of grains and seeds which determine their storability.

i. Water Content

Water contained in grains and seeds exists in two forms, the water of composition – which is the water contained within plant cells and free water on the surface of the cells – part of which is adsorbed superficially by those cells. The free moisture content determines the ability of the grains and seeds to store. For examples; most cereals and grain legumes will not keep well if their MC exceeds 13% and 15% respectively.

Maximum moisture content for long term storage of grains:

Groundnuts	-	7%	Rice	-	13%
Sorghum	-	12.5%	Paddy rice	-	14%
Wheat	-	13%	Pulse	-	15%
Maize	-	13%	Millet	-	16%

ii. Thermal Conductivity

Food grains have low specific heat and low thermal conductivity. The implication of these granular properties is that a mass of grains heats up quickly and once heated up, it losses the heat very slowly. If for any reason, there is heating in the mass of grains or seeds, the natural movement of the air between the grains will be inadequate to evacuate the heat produced. This will in turn increase arthropod pest activity as well as encourage the growth of mould. This increase rapid deterioration by the commodity.

4.0 CONCLUSION

Although traditional techniques give products that meet the organoleptic quality demands of the consumers, they are limited in terms of their utilization conditions, their low yield, the sanitary quality of their products, the rather inadequate contribution that they make toward reducing losses, and the small quantities that they can handle. Industrial technologies would have a clearly positive impact on reducing losses if their adoption was not limited by serious socioeconomic handicaps.

The various indigenous storage of crops in the country are indeed what we should be proud of as these methods are those that are effective and will be perfect if only agriculturist are willing to improve on what is already on ground. This is because personally, I do not buy the idea of using chemicals.

5.0 Summary

Taking into account the level of industrial development of Nigeria and their level of production (small, moderately unproductive family farms and wide geographical distribution), it seems that, at present, post- harvest technologies used at the cottage-industry level are the most effective and suitable solution to the problems involved in processing roots and tubers in rural environment. The proper introduction of cottage-industry technologies based on improved traditional technologies would allow root and tubers to play greater role in achieving self-sufficiency in food production in Africa. Also, definite measures should be taken to ensure the linkage of research, training, and extension in root and tuber crops production, storage, processing, and utilization. Specific action programs should be launched to facilitate rapid and widespread adoption of improved production, storage and processing technologies for these crops.

Attention should be given to handling, drying, transportation, and storage, processing and packaging of products based on the study of traditional food preparations and utilization, consumer preference in different regions and how to satisfy them with improved varieties and food procession.

6.0 Tutor Marked Assessment (TMA)

i. Explain the different traditional methods of food storage

ii. Describe the application of Insecticide Dusts for the protection of maize in storage

iii. List the three groups of biological agents that cause deterioration in stored foods

iv. Describe the problems associated with storage traditional storage of roots and tubers

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MODULE 4: STORAGE AND STORAGE-LIFE OF HARVESTED CROPS

UNIT 1: STORAGE LIFE OF HARVESTED CROP MATERIALS

UNIT 2: STORAGE AND SHELF-LIFE PROBLEM

UNIT 3: IDEAL ENVIRONMENT FOR STORAGE

UNIT 1: STORAGE LIFE OF HARVESTED CROP MATERIALS

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1.0 Introduction

Harvested fresh produce is 'living' and continues to perform its metabolic functions in the post-harvest state. These metabolic functions influence greatly on the quality and shelf life of fresh produce. A basic understanding of post-harvest physiological processes and mechanisms for their control is critical for effective quality maintenance throughout horticultural supply chains to reduce losses as well as for quality product. This component describes the physiological factors that impact on the quality of horticultural produce. Knowing the physiological processes in fresh produce and factors that influence them is important in designing measures to maintain or improve quality and reduce postharvest losses.

The Postharvest quality of a product develops during growing of produce and is maintained, quality cannot be improved after harvest. Production of high quality produce hinges on good quality inputs, good cultural practices (planting, weeding, fertilizer application etc.) as well as good hygiene management during production so as to minimize microbial and/or chemical contamination of produce. Maximum postharvest quality for any cultivar can be achieved only by understanding and managing the various roles that pre-harvest factors play in postharvest quality.

2.0Objectives

At the end of this unit you should be able to

- Describe physiological processes of fresh produce
- Describe factors that influence the physiological processes of fresh produce
- Describe the processes of water loss in fresh produce and design measures to curtail or reduce water loss process
- Describe the factors that affect the rate of respiration
- Describe pre-harvest factors that affect quality and shelf life of produce
- Explain the effect of mineral nutrition on produce quality and shelf life
- Identify and discuss those cultural practices that aid in the production of quality produce

3.1 Physiological processes of fresh produce

3.1.1 Respiration

Harvested produce is alive, which means that it is constantly respiring. Respiration involves the breakdown of carbohydrate (example sugars) and other food reserves (organic and fatty acids) in the plant or in harvested produce and results in the production of carbon dioxide, water and heat.

Respiration occurs both pre- and post-harvest.

i. **Aerobic respiration**

In the post-harvest phase, respiration is supported by carbohydrate reserves of the produce; this leads to a net loss in its dry weight or negative growth. The more rapid the respiration rate, the faster the produce will consume its carbohydrate reserves, the greater will be the heat produced and the shorter will be the post-harvest life of the fruit or vegetable.

Breaking down of glucose in the presence of oxygen leading to formation of carbon dioxide, water and energy(heat) $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6H_2O$ + Heat (2830 kJ)

Carbohydrate breakdown during respiration leads to losses in food value, flavour, texture and weight, and thus to overall quality loss. Loss in weight, in particular, results in economic loss to the producer. Every effort must, therefore, be made to slow down the respiration rate of produce in order to minimize quality losses, extend shelf life and minimize economic losses to the producer.

ii. Factors that impact on respiration rates:

- Temperature
- Atmospheric composition
- Physical stress

a. Temperature

Temperature has a significant influence on the respiration rate of harvested produce and without doubt has the greatest impact on the deterioration of produce post-harvest. The higher the storage temperature of fresh produce, the greater is its rate of respiration. The rate of deterioration of horticultural produce increases two to three-fold with every 10°C increase in temperature Respiration rates can be slowed by storing produce at a low temperature that does not cause physiological damage to the produce. Temperature management is pivotal to controlling respiration and to maintaining quality.

b. Atmospheric composition

Adequate levels of O_2 are required to support the process of aerobic respiration in harvested produce. The exact level of O_2 required to reduce respiration rates, while at the same time allowing aerobic respiration, varies in accordance with the commodity concerned. An O_2 level of around 2 to 3 per cent generally produces a beneficial reduction in respiration rates and in other metabolic reactions of fresh produce. Lower O_2 levels could lead to anaerobic respiration and off-flavour development as a result of alcohol formation.

Breaking down of glucose in the absence of oxygen (anaerobic respiration) leading to the formation of carbon dioxide and energy (heat)

$C_6H_{12}O_6 \; + \; 2\,CO_2 \rightarrow 2C_2H_5OH + \text{Heat (118 kJ)}$

(Anaerobic respiration)

Post-harvest handling treatments such as waxing, coating, film wrapping and controlled atmosphere packaging can be used to regulate the availability of oxygen to harvested produce and so to reduce respiration rates.

c. Physical stress

Mild physical stress can perturb the respiration rates of produce. Bruising can, for example, result in substantial increases in the respiration rate of harvested produce. The avoidance of mechanical injury through proper packaging and handling is critical to assuring produce quality.

3.1.2Transpiration or water loss

Fresh produce contains between 70 and 95 % water and is losing water constantly to the environment in the form of water vapour. The rate of water loss varies in accordance with morphological characteristics (such as tissue structure, dimensions and number of stomata and the presence of a waxy layer) of the epidermis (skin) of the produce item, the exposed surface area of the produce and the vapour pressure deficit (VPD) between the produce and its environment. The VPD bears an inverse relationship to the relative humidity of the environment. Under conditions of low relative humidity the VPD is high and water is lost rapidly. The rate of water loss increases exponentially with increasing temperature and linearly under conditions of low relative humidity.

Water lost due to transpiration in harvested produce cannot be replaced, thus resulting in wilting, shriveling, loss of firmness, crispiness, succulence and overall loss of freshness. These undesirable changes in appearance, texture and flavour, coupled with weight loss, greatly reduce the economic value of horticultural produce. Wilted leafy vegetables may, for example, require excessive trimming to make them marketable.

Water loss can be controlled through temperature management, packaging and adjustment of the relative humidity of the storage environment of the produce. However, care must be taken to avoid condensation of moisture on the surface of the produce, since this could contribute to the development of decay.

3.1.3Ethylene production

Ethylene (C_2H_4) is a naturally occurring organic molecule that is a colourless gas at biological temperatures. Ethylene is synthesized in small quantities by plants and appears to co-ordinate their growth and development. It is also associated with the decomposition of wounded produce. Given its gaseous nature, ethylene readily diffuses from the sites where it is produced. Continuous synthesis is, therefore, needed for maintenance of biologically active levels of ethylene in plant tissues.

Ethylene is also an environmental pollutant, being produced by internal combustion engines, propane powered equipment, cigarette smoke and rubber materials exposed to ultra violet light. Fresh produce can be categorized as being either climacteric or non-climacteric on the basis of its ability to produce ethylene during the ripening process.

• **Climacteric crops –** produce a burst of ethylene and show an increase in respiration on ripening. Ripening of climacteric fruit after harvest typically involves softening and a change in colour and taste in terms of sweetness.

3.1.4 Mechanical injuries.

Various types of physical damage (surface injuries, impact bruising, and vibration bruising and so on) are major contributors to deterioration. Browning of damaged tissues results from membrane disruption, which exposes phenolic compounds to the polyphenol oxidase enzyme. Mechanical injuries not only are unsightly but also accelerate water loss, provide sites for fungal infection and stimulate CO_2 and C_2H_4 production by the commodity.

3.1.5 Pathological breakdown

One of the most common and obvious symptoms of deterioration results from the activity of bacteria and fungi. Attack by most organisms follows physical injury or physiological breakdown of commodity. In a few cases, pathogens can infect apparently healthy tissues and become the primary cause of deterioration. In general, fruits and vegetables exhibit considerable resistance to potential pathogens during most of their post harvest life. The onset of ripening in fruits and senescence in all commodities renders them susceptible to infection by pathogens. Stresses such as mechanical injuries, chilling and sunscald lower the resistance to pathogens.

3.2Pre-harvest factors on post-harvest life

The postharvest quality of a product develops during growing of produce and is maintained, quality cannot be improved after harvest. Therefore, the goal of a producer is to supply safe, high-quality produce, which confirms to consumer and market requirements. This objective hinges on good quality inputs, good cultural practices (planting, weeding, fertilizer application etc.) as well as good hygiene management during production so as to minimize microbial and/or chemical contamination of produce.

Pre-harvest factors often interact in complex ways that depend on specific cultivar characteristics and growth or development age sensitivities. The tremendous diversity of fruits and vegetables that are produced commercially and the general lack of research relating pre-harvest factors to post harvest quality preclude generalizations about pre-harvest influences that uniformly apply to all fruits and vegetables. Maximum postharvest quality for any cultivar can be achieved only by understanding and managing the various roles that pre-harvest factors play in postharvest quality.

3.2.1Cultivar and rootstock genotype

Cultivar and rootstock genotype have an important role in determining the taste, quality, yield, nutrient composition, and postharvest life of fruits and vegetables. The incidence and severity of decay, insect damage, and physiological disorders can be reduced by choosing the correct genotype for given environmental conditions. Breeding programs are constantly creating new cultivars and rootstocks with improved quality and better adaptability to various environmental and crop pest conditions.

Some experts consider the most important cultivar characteristic for fruits and vegetables to be disease resistance, including resistance to diseases that diminish postharvest quality. Control of some postharvest diseases may include breeding for resistance to the vector (e.g., aphid, nematode, leafhopper, or mite), rather than just for the pathogen.

Nutritional quality may also vary greatly according to cultivar. L-ascorbic acid levels in different pepper types also vary considerably. For example, in jalapeno peppers, the highest ascorbic acid levels were in Jaloro (131 mg100g-1) and the lowest were in Mitla (49 mg 100g-1). Wide variation in beta-carotene content of several cultivars of sweet potato has similarly been reported; Georgia Jet, suggested for processing, contained low concentrations of beta-carotene (6.9 mg 100g-l). There is a need to identify and develop cultivars that are suitable for processing and high in antioxidant vitamin content.

Genetic engineering can be a successful tool in altering the quality and yield of certain vegetables, but its commercial application will depend largely on consumer acceptance and food safety issues. Future advances will depend on successful team efforts between plant breeders, plant pathologists, molecular geneticists, and consumer education programs.

3.2.2Mineral nutrition

Nutritional status is an important factor in quality at harvest and postharvest life of various fruits and vegetables. Deficiencies, excesses, or imbalances of various nutrients are known to result in disorders that can limit the storage life of many fruits and vegetables. Fertilizer application rates vary widely among growers and generally depend upon soil type, cropping history; and soil test results, which help indicate nitrogen (N), phosphorous (P), and potassium (K) requirements. To date, fertilization recommendations for fruits and vegetables have been established primarily for productivity goals, not as diagnostics for good flavor quality and optimal postharvest life.

The nutrient with the single greatest effect on fruit quality is nitrogen. Response of peach and nectarine trees to nitrogen fertilization is dramatic. High nitrogen levels stimulate vigorous vegetative growth, causing shading and death of lower fruiting wood. Although high-nitrogen trees may look healthy and lush, excess nitrogen does not increase fruit size, production, or soluble solids content (SSC). Furthermore, excessive nitrogen delays stone fruit maturity, induces poor red colour development, and inhibits ground colour change from green to yellow. However, nitrogen deficiency leads to small fruit with poor flavor and unproductive trees.

In vegetable crops, excessive nitrogen levels induce delayed maturity and increase several disorders that diminish postharvest quality. Disorders such as grey wall or internal browning in tomato, hollow stem of broccoli, lower soluble solids concentration in potato, fruit spot in peppers, and growth cracks and hollow heart in broccoli and cauliflower have been associated with high nitrogen. High nitrogen has also been associated with increased weight loss during storage of sweet potatoes and soft rot in tomatoes. Excessive soil nitrogen can negatively impact vegetable quality in several ways. High nitrogen can result in composition changes such as reduced ascorbic acid (vitamin C) content, lower sugar content, lower acidity, and altered ratios of essential amino acids. In leafy green vegetables grown under low light, it can result in the accumulation of nitrates in plant tissues to unhealthy levels. High nitrogen fertilization can lead to reduced volatile production and changes in the characteristic flavor of celery.

Although calcium is classified as a secondary nutrient, it is involved in numerous biochemical and morphological processes in plants and has been implicated in many disorders of considerable economic importance to the production and postharvest quality of fruits and vegetables. Bitter pit in apple, corks pot in pear, blackheart in celery, blossom end rot in tomato, cavity spot and cracking in carrot, and tip burn of lettuce are calcium deficiency disorders that reduce the quality and marketability of these commodities. Certain calcium deficiency disorders, such as bitter pit in apples and blossom end rot in tomatoes, may be lessened through proper irrigation, fertilizer management, and supplemental fertilization. However, for tip bum of lettuce, a physiological disorder caused by the lack of mobility of calcium in the heads during warm weather and rapid growing conditions, there is currently no pre-harvest control practice.

3.2.3 Irrigation

Despite the important role of water in fruit growth and development, few studies have been done on the influence of the amount and the timing of water applications on fruit and vegetable quality at harvest and during postharvest.

Water management as a direct determinant of postharvest quality has also been investigated for a number of vegetables produced in semiarid irrigated regions such as California and Israel. Except for a few studies, however, which have comprehensively tested a broad range of water management practices and conditions and their impacts on postharvest quality; it is often difficult to generalize about the effects of water management from the site-specific irrigation regimes that have been reported.

There is considerable evidence that water stress at the end of the season, which may be achieved by irrigation cutoff or deficit irrigation relative to evapo-transpirative demand for generally more than 20 days prior to harvest, may markedly improve SSC in tomatoes. Irrigation cutoffs may also facilitate harvests and minimize soil compaction from mechanical harvest operations. Late-season irrigations with saline water have also been shown to increase tomato SSC. Although a higher SSC may result in premiums paid to producers, because of the link between applied water and yield, irrigation practices typically aim at the best overall economic balance between productivity and quality.

Melon postharvest quality is also quite sensitive to water management. Over irrigation can result not only in low SSC in melons but also unsightly ground spots and fruit rots (and measles in honeydews). Rapid growth resulting from irrigations following extended periods of soil water deficits may result in growth cracks in carrots, potatoes, tomatoes, and several other vegetable crops. Uneven irrigation management may also increase the incidence of "spindle"- or "dumb-bell “shaped potatoes, depending on the growth stage during which soil Water was limited. Postharvest losses due to storage diseases such as neck rot, black rot, basal rot, and bacterial rot of onions can be influenced by irrigation management. Selecting the proper irrigation system relative to the crop stage of growth, reducing the number of irrigations applied, and assuring that onions cure adequately prior to harvest can help prevent storage losses.

Management of water frequently poses a dilemma between yield and postharvest quality. A deficiency or excess of water may influence postharvest quality of berry crops. Extreme water stress reduces yield and quality; mild water stress reduces crop yield but may improve some quality attributes in the fruit; and no water stress increases yield but may reduce postharvest quality. In strawberries, reduction of water stress by natural rainfall or irrigation during maturation and ripening decreases firmness and sugar con- tent and provides more favorable conditions for mechanical fruit injury and rot. If straw- berry plants are overirrigated, especially at harvest, the fruit is softer and more susceptible to bruising and decay.

3.2.4Crop rotations

Crop rotation may be an effective management practice for minimizing postharvest losses by reducing decay inoculums in a production field. Because soil borne fungi, bacteria, and nematodes can build up to damaging levels with repeated cropping of a single vegetable crop, rotations out of certain vegetables are commonly recommended in intensive vegetable production regions. Four-year rotations with non-cucurbit crops are routinely recommended for cucurbit disease management, as are 4-year rotations for garlic to decrease postharvest disease incidence. There is also evidence that the use of plastic mulches can increase postharvest losses from decay in vegetables such as tomatoes.

4.0 Conclusion

A basic understanding of post-harvest physiological processes i.e. respiration, transpiration, ethylene production, pathological break down, and mechanical injuries and mechanisms for their control is critical for effective quality maintenance throughout horticultural supply chains to reduce losses as well as for quality product. This component describes the physiological factors that impact on the quality of horticultural produce. Knowing the physiological processes in fresh produce and factors that influence them is important in designing measures to maintain or improve quality and reduce postharvest losses. The Postharvest quality of a product develops during growing of produce and is maintained, quality cannot be improved after harvest.This objective hinges on good quality inputs, good cultural practices (planting, weeding, fertilizer application etc.) as well as good hygiene management during production so as to minimize microbial and/or chemical contamination of produce.

5.0 Summary

These metabolic functions (i.e. respiration, transpiration and ethylene production) influence greatly the quality and shelf life of fresh produce. A basic understanding of post-harvest physiological processes and mechanisms for their control is critical for effective quality maintenance throughout horticultural supply chains to reduce losses as well as for quality product**.** Temperature has a significant influence on the respiration rate of harvested produce and without doubt has the greatest impact on the deterioration of produce post-harvest quality. Maximum postharvest quality for any cultivar can be achieved only by understanding and managing the various roles that pre-harvest factors play in postharvest quality.

6.0 Tutor Marked Assignment (TMA)

- Describe the process of respiration and its effect on produce quality
- Explain the terms climacteric and non-climacteric fruits

- Enumerate the factors that impact on rates of respiration
- Describe the role of cultivar genotype in determining the quality of crop produce
- Explain the impact of irrigation on postharvest quality of crop produce

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UNIT 2 STORAGE AND SHELF-LIFE PROBLEMS

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1.0 Introduction

It is estimated that in the tropics each year between 25 and 40% of stored agricultural products is lost because of inadequate farm- and village-level storage. In the field and during storage the products are threatened by insects, rodents, birds and other pests. Moreover, the product may be spoiled by infection from fungi, yeasts or bacteria. In addition, for sowing seed it is important that the viability (its capacity to germinate) is maintained. In order to minimize the losses during storage it is important to know the optimum environmental conditions for storage of the product, as well as the conditions under which its attackers flourish.

2.0Objectives

At the end of this unit you should be able to answer the following questions

- Describe ideal temperature and relative humidity for the storage of most fruits and vegetables
- Suggest measures that could minimize primary loss of crop produce
- Describe problems of crop storage
- Carry out storage of some crop produce based on the knowledge acquired in this unit
- Describe methods of shelf-life extension of crop produce by canning
- Describe drying as a method of extending shelf life of crop produce
- Describe freezing as a method of shelf life extension

3.0 Problems of crop storage

i. Temperature

It is of greatest importance that a roof is constructed above the silos in such a way that it extends far enough to protect the walls against full sunlight. This lowers the inside temperature, lessens temperature changes between day and night and reduces the chance of local heating, which causes condensation in other, cooler spots with consequent fungus growth. One can also use building materials which do not easily pass on changes in outside temperatures to the stored grains (good insulators), or one can paint the containers white.

ii. Moisture

Moisture may enter the storage container via the ground, the walls or the roof. A good overhanging roof protects the walls against rain. In order to prevent moisture coming up from the ground, the gourds, baskets, sacks etc. should always be placed on a dry under floor or on a platform of bricks or wooden poles. Floors of stone or concrete can be laid on a moisture barrier made of metal foil, tar paper, plastic and/or should have a waterproof layer of cement of 1 cm thickness (weight ratio water: cement: sand = 0.3:1:3).During storage in the rainy season moisture from the air can also enter via the walls of the silo, unless this is taken into account when choosing and building the silo (airtight storage).

iii. Insects

First of all it is important to keep the storage room and the surrounding area as clean as possible, especially when using a non-airtight storage method. Put a clean product into a container, only after all old products, dust, straw and insects have been removed, and all cracks and holes have been filled and sealed. One should distinguish between insects that are already present in the product to be stored and insects that may enter the storage room during storage.

Prevent further development of the insects by:

- Airtight storage
- Sunning. Insects leave grain which is placed in hot sunlight as they do not like temperatures higher than 40 - 50 °C. The sunning process, however, does not always kill eggs and larvae present inside the grain itself.
- Mixing the grains with wood ash (or ash of burned rice husks), burned cow dung, fine sand, lime, diatomaceous earth or certain types of kaolin clay. Volume ratios of ash: grain = 1:1 to 1:2, and clay: grain = 1:10. The effect of kaolin clay is greatly enhanced if sulphuric or hydrochloric acid is added and subsequently heated to 400 °C. The materials used, fill the spaces between the grains, thereby restricting insect movement and emergence. A similar method is the admixture of small cereal grains, for example millet, with maize or sorghum. Certain vegetable oils, such as palm and groundnut oil, applied to pulses, give protection against bruchids (a kind of beetle)
- Mixing local plants with the grains. In many areas, local plants are known of which the roots, leaves, flowers and/or fruits (dried and ground) act as a repellents.

iv. Domestic animals

These can be kept away by building a fence around the silo, made out of wood, bamboo or other local materials. A stack of twigs around the silo is also sufficient. Take care that it does not become a hiding place for rats.

v. Thieves

Theft is made more difficult if the fill- and outflow openings are made in such a way that they can be locked. It is also possible to construct a silo without an outflow.

3.1 Recommended Temperature and Relative Humidity, and Approximate Transit and Storage Life for Fruits and Vegetable Crops

Table 3.1.1 Recommended Temperature and Relative Humidity, and Approximate Transit and Storage Life for Fruits and Vegetable Crops

Product	Temperature		Relative Humidity (percent)	Approximate storage life
	°C	°F		
Amaranth	0-2	32-36	95-100	10-14 days
Anise	0-2	32-36	90-95	2-3 weeks
Apples	-1-4	30-40	90-95	1-12 months
Apricots	-0.5-0	31-32	90-95	1-3 weeks
Artichokes, globe	0	32	95-100	2-3 weeks
Asian pear	1	34	90-95	5-6 months
Asparagus	0-2	32-35	95-100	2-3 weeks
Atemoya	13	55	85-90	4-6 weeks
Avocados, Fuerte, Hass	7	45	85-90	2 weeks
Avocados, Lula, Booth-1	4	40	90-95	4-8 weeks
Avocados, Fuchs, Pollock	13	55	85-90	2 weeks
Babaco	7	45	85-90	1-3 weeks
Bananas, green	13-14	56-58	90-95	14 weeks
Barbados cherry	0	32	85-90	7-8 weeks
Bean sprouts	0	32	95-100	7-9 days
Beans, dry	4-10	40-50	40-50	6-10 months
Beans, green or snap	4-7	40-45	95	7-10 days
Beans, lima , in pods	5-6	41-43	95	5 days
Beets, bunched	0	32	98-100	10-14 days
Beets, topped	0	32	98-100	4-6 months
Belgian endive	2-3	36-38	95-98	24 weeks
Bitter melon	12-13	53-55	85-90	2-3 weeks

Black sapote	13-15	55-60	85-90	2-3 weeks
Blackberries	-0.5-0	31-32	90-95	2-3 days
Blood orange	4-7	40-44	90-95	3-8 weeks
Blueberries	-0.5-0	31-32	90-95	2 weeks
Bok choy	0	32	95-100	3 weeks
Boniato	13-15	55-60	85-90	4-5 months
Breadfruit	13-15	55-60	85-90	2-6 weeks
Broccoli	0	32	95-100	10-14 days
Brussels sprouts	0	32	95-100	3-5 weeks
Cabbage, early	0	32	98-100	3-6 weeks
Cabbage, late	0	32	98-100	5-6 months
Cactus Leaves	2-4	36-40	90-95	3 weeks
Cactus Pear	2-4	36-40	90-95	3 weeks
Caimito	3	38	90	3 weeks
Calabaza	10-13	50-55	50-70	2-3 months
Calamondin	9-10	48-50	90	2 weeks
Canistel	13-15	55-60	85-90	3 weeks
Cantaloupes (3/4-slip)	2-5	36-41	95	15 days
Cantaloupes (full-slip)	0-2	32-36	95	5-14 days
Carambola	9-10	48-50	85-90	3-4 weeks
Carrots, bunched	0	32	95-100	2 weeks
Carrots, mature	0	32	98-100	7-9 months
Carrots, immature	0	32	98-100	4-6 weeks
Cashew apple	0-2	32-36	85-90	5 weeks
Cauliflower	0	32	95-98	34 weeks
Celeriac	0	32	97-99	6-8 months
Celery	0	32	98-100	2-3 months
Chard	0	32	95-100	10-14 days
Chayote squash	7	45	85-90	4-6 weeks
Cherimoya	13	55	90-95	2-4 weeks
Cherries, sour	0	32	90-95	3-7 days
Cherries, sweet	-1 to -0.5	30-31	90-95	2-3 weeks
Chinese broccoli	0	32	95-100	10-14 days
Chinese cabbage	0	32	95-100	2-3 months
Chinese long bean	4-7	40-45	90-95	7-10 days
Clementine	4	40	90-95	24 weeks
Coconuts	0-1.5	32-35	80-85	1-2 months
Collards	0	32	95-100	10-14 days
Corn, sweet	0	32	95-98	5-8 days
Cranberries	2-4	36-40	90-95	24 months

Cucumbers	10-13	50-55	95	10-14 days
Currants	-0.5-0	31-32	90-95	1-4 weeks
Custard apples	5-7	41-45	85-90	4-6 weeks
Daikon	0-1	32-34	95-100	4 months
Dates	-18 or 0	0 or 32	75	6-12 months
Dewberries	-0.5-0	31-32	90-95	2-3 days
Durian	4-6	39-42	85-90	6-8 weeks
Eggplants	12	54	90-95	1 week
Elderberries	-0.5-0	31-32	90-95	1-2 weeks
Endive and escarole	0	32	95-100	2-3 weeks
Feijoa	5-10	41-50	90	2-3 weeks
Figs fresh	-0.5-0	31-32	85-90	7-10 days
Garlic	0	32	65-70	6-7 months
Ginger root	13	55	65	6 months
Gooseberries	-0.5-0	31-32	90-95	34 weeks
Granadilla	10	50	85-90	3-4 weeks
Grapefruit, Calif.&Ariz.	14-15	58-60	85-90	6-8 weeks
Grapefruit, Fla.&Texas	10-15	50-60	85-90	6-8 weeks
Grapes, Vinifera	-1 to -0.5	30-31	90-95	1-6 months
Grapes, American	-0.5-0	31-32	85	2-8 weeks
Greens, leafy	0	32	95-100	10-14 days
Guavas	5-10	41-50	90	2-3 weeks
Haricot vert (fine beans)	4-7	40-45	95	7-10 days
Horseradish	-1-0	30-32	98-100	10-12 months
Jaboticaba	13-15	55-60	90-95	2-3 days
Jackfruit	13	55	85-90	2-6 weeks
Jaffa orange	8-10	46-50	85-90	8-12 weeks
Japanese eggplant	8-12	46-54	90-95	1 week
Jerusalem Artichoke	-0.5-0	31-32	90-95	+5 months
Jicama	13-18	55-65	65-70	1-2 months
Kale	0	32	95-100	2-3 weeks
Kiwano	10-15	50-60	90	6 months
Kiwifruit	0	32	90-95	3-5 months
Kohlrabi	0	32	98-100	2-3 months
Kumquats	4	40	90-95	2-4 weeks
Langsat	11-14	52-58	85-90	2 weeks
Leeks	0	32	95-100	2-3 months
Lemons	10-13	50-55	85-90	1-6 months
Lettuce	0	32	98-100	2-3 weeks
Limes	9-10	48-50	85-90	6-8 weeks

Lo bok	0-1.5	32-35	95-100	24 months
Loganberries	-0.5-0	31-32	90-95	2-3 days
Longan	1.5	35	90-95	3-5 weeks
Loquats	0	32	90	3 weeks
Lychees	1.5	35	90-95	3-5 weeks
Malanga	7	45	70-80	3 months
Mamey	13-15	55-60	90-95	2-6 weeks
Mangoes	13	55	85-90	2-3 weeks
Mangosteen	13	55	85-90	2-4 weeks
Melons:				
Casaba	10	50	90-95	3 weeks
Crenshaw	7	45	90-95	2 weeks
Honeydew	7	45	90-95	3 weeks
Persian	7	45	90-95	2 weeks
Mushrooms	0	32	95	34 days
Nectarines	-0.5-0	31-32	90-95	2-4 weeks
Okra	7-10	45-50	90-95	7-10 days
Olives, fresh	5-10	41-50	85-90	+6 weeks
Onions, green	0	32	95-100	34 weeks
Onions, dry	0	32	65-70	1-8 months
Onion sets	0	32	65-70	6-8 months
Oranges , Calif.&Ariz.	3-9	38-48	85-90	3-8 weeks
Oranges , Fla.&Texas	0-1	32-34	85-90	8-12 weeks
Papayas	7-13	45-55	85-90	1-3 weeks
Passionfruit	7-10	45-50	85-90	3-5 weeks
Parsley	0	32	95-100	2-2.5 months
Parsnips	0	32	95-100	+6 months
Peaches	-0.5-0	31-32	90-95	2-4 weeks
Pears	-1.5 to -0.5	29-31	90-95	2-7 months
Peas, green	0	32	95-98	1-2 weeks
Peas, southern	4-5	40-41	95	6-8 days
Pepino	4	40	85-90	1 month
Peppers, Chili (dry)	0-10	32-50	60-70	6 months
Peppers, sweet	7-13	45-55	90-95	2-3 weeks
Persimmons, Japanese	-1	30	90	34 months
Pineapples	7-13	45-55	85-90	24 weeks
Plantain	13-14	55-58	90-95	1-5 weeks
Plums and prunes	-0.5-0	31-32	90-95	2-5 weeks
Pomegranates	5	41	90-95	2-3 months
Potatoes, early crop	10-16	50-60	90-95	10-14 days

Potatoes, late crop	4.5-13	40-55	90-95	5-10 months
Pummelo	7-9	45-48	85-90	12 weeks
Pumpkins	10-13	50-55	50-70	2-3 months
Quinces	-0.5-0	31-32	90	2-3 months
Raddichio	0-1	32-34	95-100	2-3 weeks
Radishes, spring	0	32	95-100	34 weeks
Radishes, winter	0	32	95-100	24 months
Rambutan	12	54	90-95	1-3 weeks
Raspberries	-0.5-0	31-32	90-95	2-3 days
Rhubarb	0	32	95-100	24 weeks
Rutabagas	0	32	98-100	+6 months
Salsify	0	32	95-98	2-4 months
Santol	7-9	45-48	85-90	3 weeks
Sapodilla	16-20	60-68	85-90	2-3 weeks
Scorzonera	0-1	32-34	95-98	6 months
Seedless cucumbers	10-13	50-55	85-90	10-14 days
Snow peas	0-1	32-34	90-95	1-2 weeks
Soursop	13	55	85-90	1-2 weeks
Spinach	0	32	95-100	10-14 days
Squashes, summer	5-10	41-50	95	1-2 weeks
Squashes, winter	10	50	50-70	2-3 months
Strawberries	0	32	90-95	5-7 days
Sugar apples	7	45	85-90	4 weeks
Sweetpotatoes	13-15	55-60	85-90	4-7 months
Tamarillos	3-4	37-40	85-95	10 weeks
Tamarinds	7	45	90-95	3-4 weeks
Tangerines, mandarins, and related citrus fruits	4	40	90-95	24 weeks
Taro root	7-10	45-50	85-90	4-5 months
Tomatillos	13-15	55-60	85-90	3 weeks
Tomatoes, mature-green	18-22	65-72	90-95	1-3 weeks
Tomatoes, firm-ripe	13-15	55-60	90-95	4-7 days
Turnips	0	32	95	4-5 months
Turnip greens	0	32	95-100	10-14 days
Ugli fruit	4	40	90-95	2-3 weeks
Waterchestnuts	0-2	32-36	98-100	1-2 months
Watercress	0	32	95-100	2-3 weeks
Watermelons	10-15	50-60	90	2-3 weeks
White sapote	19-21	67-70	85-90	2-3 weeks
White asparagus	0-2	32-36	95-100	2-3 weeks
Winged bean	10	50	90	4 weeks

Yams	16	61	70-80	6-7 months
Yucca root	0-5	32-41	85-90	1-2 months

Source: McGregor, B.M. 1989. Tropical Products Transport Handbook. USDA Office of Transportation, Agricultural Handbook 668.

3.2 Methods of Shelf life extension

3.2.1 Canning

Canning is a method of preserving food in which the food is processed and sealed in an airtight container. The process was first developed as a French military discovery by Nicolas Appert. The packaging prevents microorganisms from entering and proliferating inside.

To prevent the food from being spoiled before and during containment, quite a number of methods are used: pasteurization, boiling (and other applications of high temperature over a period of time), refrigeration, freezing, drying, vacuum treatment, antimicrobial agents that are natural to the recipe of the foodstuff being preserved, a sufficient dose of ionizing radiation, submersion in a strongly saline, acid, base, osmotic ally extreme (for example very sugary) or other microbe-challenging environments.

No such method is perfectly dependable as a preservative. For example, spore forming thermal resistant microorganisms, such as Clostridium botulinum (which causes botulism) can still survive.

From a public safety point of view, foods with low acidity (a pH more than 4.6) need sterilization under high temperature (116-130°C). To achieve temperatures above the boiling point requires the use of a pressure canner. Foods that must be pressure canned include most vegetables, meats, seafood, poultry, and dairy products. The only foods that may be safely canned in an ordinary boiling water bath are highly acidic ones with a pH below 4.6 such as fruits, pickled vegetables, or other foods to which acidic additives have been added.

3.2.2 Drying

One of the oldest methods of Shelf life extension is by drying, which reduces water activity sufficiently to prevent or delay bacterial growth. Drying also reduces weight, making food more portable. Most types of meat can be dried; a good example is beef biltong. Many fruits can also be dried; for example, the process is often applied to apples, pears, bananas, mangoes, papaya, apricot, and coconut. Zante currants, sultanas and raisins are all forms of dried grapes. Drying is also the normal means of preservation for cereal grains such as wheat, maize, oats, barley, rice, millet and rye.

3.2.3 Freezing

Freezing is also one of the most commonly used processes commercially and domestically for preserving a very wide range of food including prepared food stuffs which would not have required freezing in their unprepared state. For example, potato waffles are stored in the freezer, but potatoes themselves require only a cool dark place to ensure many months' storage. Cold stores provide large volume, long-term storage for strategic food stocks held in case of national emergency in many countries.

3.2.4 Vacuum packing

Vacuum-packing stores food in a vacuum environment, usually in an air-tight bag or bottle. The vacuum environment strips bacteria of oxygen needed for survival, slowing spoiling. Vacuum-packing is commonly used for storing nuts to reduce loss of flavor from oxidation.

3.2.5 Sugar

Sugar is used to preserve fruits, either in syrup with fruit such as apples, pears, peaches, apricots, plums or in crystallized form where the preserved material is cooked in sugar to the point of crystallization and the resultant product is then stored dry. This method is used for the skins of citrus fruit (candied peel), angelica and ginger. A modification of this process produces glace fruit such as glace cherries where the fruit is preserved in sugar but is then extracted from the syrup and sold, the preservation being maintained by the sugar content of the fruit and the superficial coating of syrup. The use of sugar is often combined with alcohol for preservation of luxury products such as fruit in brandy or other spirits. These should not be confused with fruit flavored spirits such as cherry brandy or Sloe gin.

3.2.6 Canning and bottling

Canning involves cooking food, sealing it in sterile cans or jars, and boiling the containers to kill or weaken any remaining bacteria as a form of sterilization, inventor Nicolas Appert. Various foods have varying degrees of natural protection against spoilage and may require that the final step occur in a pressure cooker. High-acid fruits like strawberries require no preservatives to can and only a short boiling cycle, whereas marginal fruits such as tomatoes require longer boiling and addition of other acidic elements. Low acid foods, such as vegetables and meats require pressure canning. Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened.

Lack of quality control in the canning process may allow ingress of water or micro-organisms. Most such failures are rapidly detected as decomposition within the can causes gas production and the can will swell or burst. However, there have been examples of poor manufacture (under processing) and poor hygiene allowing contamination of canned food by the obligate anaerobe Clostridium botulinum, which produces an acute toxin within the food, leading to severe illness or death. This organism produces no gas or obvious taste and remains undetected by taste or smell. Its toxin is denatured by cooking, though. Cooked mushrooms, handled poorly and then canned, can support the growth of Staphylococcus aureus, which produces a toxin that is not destroyed by canning or subsequent reheating.

3.2.7 Pulsed Electric Field Processing

Pulsed electric field (PEF) processing is a method for processing cells by means of brief pulses of a strong electric field. PEF holds potential as a type of low temperature alternative pasteurization process for sterilizing food products. In PEF processing, a substance is placed between two electrodes, then the pulsed electric field is applied. The electric field enlarges the pores of the cell membranes which kills the cells and releases their contents. PEF for food processing is a developing technology still being researched. There have been limited industrial applications of PEF processing for the pasteurization of fruit juices.

3.2.8 High pressure

High pressure Shelf life extension refers to high pressure used for Shelf life extension. "Pressed inside a vessel exerting 70,000 pounds per square inch or more, food can be processed so that it retains its fresh appearance, flavour, texture and nutrients while disabling harmful microorganisms and slowing spoilage." By 2001, adequate commercial equipment was developed so that by 2005 the process was being used for products ranging from orange juice to guacamole to deli meats and widely sold.

4.0Conclusion

Anything that increases the rate at which a product's food and water reserves are used up increases the likelihood of losses. Increases in normal physiological changes can be caused by high temperature, low atmospheric humidity and physical injury. Such injury often results from careless handling, causing internal bruising, splitting and skin breaks, thus rapidly increasing water loss. To prevent the food from being spoiled before and during containment, quite a number of methods are used: pasteurization, boiling (and other applications of high temperature over a period of time), refrigeration, freezing, drying, vacuum treatment, antimicrobial agents that are natural to the recipe of the foodstuff being preserved, a sufficient dose of ionizing radiation, submersion in a strongly saline, acid, base, osmotic ally extreme (for example very sugary) or other microbe-challenging environments.

5.0 Summary

There are so many causes for losses in the post-harvest food chain that it helps to classify them into two groups primary and secondary causes of loss. Microbiological, mechanical and physiological factors cause most of the losses in perishable crops. Respiration is a continuing process in a plant and cannot be stopped without damage to the growing plant or harvested produce. It uses stored starch or sugar and stops when reserves of these are exhausted, leading to ageing and loss of quality. To prevent the food from being spoiled before and during containment, quite a number of methods are used: pasteurization, boiling (and other applications of high temperature over a period of time), refrigeration, freezing, drying, vacuum treatment, antimicrobial agents that are natural to the recipe of the foodstuff being preserved, a sufficient dose of ionizing radiation, submersion in a strongly saline, acid, base, osmotic ally extreme (for example very sugary) or other microbe-challenging environments.

6.0Tutor Marked Assignment (TMA)

- Describe the problems encountered during storage of crop produce
- Describe canning as a method of shelf life extension
- Describe drying as a method of shelf-life extension
- Describe freezing as a method of shelf-life extension
- Describe high pressure as a method of shelf-life extension

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UNIT 3: IDEAL ENVIRONMENT FOR STORAGE

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1.0 Introduction

Temperature management is important throughout the period between harvest and consumption in order to maintain good produce quality. Cooling practices provide marketing flexibility by making it possible to market produce at the optimum time and over longer distances. Presents a variety of packing methods and packaging materials that canhelp to maintain product quality and reduce mechanical damage during handling, transport and storage.

2.0 Objectives

At the end of studying this unit you should be able to:

- Describe ideal conditions for storage of crop produce
- Explain the principles of controlled atmosphere storage
- Explain the importance of pre-cooling
- Be able to compare different pre-cooling systems
- Describe the processes that could lead to loss of quality during transportation of crop produce and the measures that could be employed in overcoming them
- To successfully transport crop produce

- Explain the importance of proper packaging and the principles involved in packaging.
- Demonstrate competence in selecting the appropriate packaging container and packaging techniques for a produce item and for different target markets.

3.0 Conditions for crop storage

Storage may be defined as the act of preserving and keeping agricultural produce or any commodity for future use without necessarily losing its quality. There should be little or no change in chemical or physical condition as to reduce its quality. Thus, the main objectives of storage is to preserve the produce such that it will still be valuable and useful to the ultimate consumer

Produce can be stored for both short-term and long-term purposes. Short-term storage is mainly used to provide flexibility in marketing (e.g. when awaiting transport), or because buyers are not immediately available. Most horticultural crops are perishable and can only be stored for a few days. Only rarely is it worthwhile storing perishable crops to await higher prices, as storage will reduce quality and shelf life whilst adding to costs. Storage is costly and, in most instances, when the produce is withdrawn from storage it has to compete in the market against much fresher produce.

A few crops are adapted for long-term storage. These can be held in store well beyond the normal harvesting period. When they are eventually sold higher prices can usually be obtained and, by extending the marketing season, a larger volume of produce can be marketed. Often, the most successful stores are located in urban areas because

If produce is to be stored, it is important to begin with a high quality product. The lot of produce must not contain damaged or diseased units, and containers must be well ventilated and strong enough to withstand stacking. In general, proper storage practices include temperature control, relative humidity control, air circulation and maintenance of space between containers for adequate ventilation, and avoiding incompatible product mixes.

Commodities stored together should be capable of tolerating the same temperature, relative humidity and level of ethylene in the storage environment. High ethylene producers (such as ripe bananas, apples, cantaloupe) can stimulate physiological changes in ethylene sensitive commodities (such as lettuce, cucumbers, carrots, potatoes, sweet potatoes) leading to often undesirable color, flavor and texture changes.

3.1 Cooling and Storage

Temperature management is important throughout the period between harvest and consumption in order to maintain good produce quality. Cooling practices provide marketing flexibility by making it possible to market produce at the optimum time and over longer distances. In order to select the best cooling method, it is necessary to understand the basic principles of cooling.

Importance of pre-cooling

Pre-cooling prior to shipment, storage or processing is essential for the removal of field heat from many perishable crops.

Proper pre-cooling can:

- prevent quality loss due to softening by suppressing enzymatic degradation and respiratory activity;
- prevent wilting by slowing or inhibiting water loss;
- slow the rate of decay of produce by slowing or inhibiting the growth of decay-producing micro-organisms (moulds and bacteria);
- reduce the rate of ethylene production; and
- minimize the impact of ethylene on ethylene sensitive produce items.

Factors that govern the selection of a pre-cooling technology

The choice of cooling methods is dependent on a number of considerations:

- Nature of the produce, e.g. fruit or vegetable – different types of produce have different cooling requirements. Strawberries and broccoli, for example, require near-freezing temperatures, whereas similarly low temperatures would damage bananas, mangoes or tomatoes.
- Package design – the level of package ventilation (i.e. number and size of ventilation holes) as well as palletisation design can greatly impact on the rate of product cooling.
- Product flow capacity – some methods of cooling are more efficient than others. Rapid cooling methods, in general, are required for the efficient cooling of large product volumes.
- Economic factors – construction and operating costs vary among cooling methods. The selection of a cooling procedure must be justified by the volume and selling price of the produce

item. In cases where small volumes of produce are available and where electricity costs are high, higher-cost methods of cooling cannot be used since the cost incurred cannot be justified by the end profit margins.

• Social factors – in low-income areas and in areas that lack electricity or cooling infrastructure, the use of simple and appropriate, inexpensive cooling methods makes sense.

Pre-cooling technologies

A. Cooling with cold air

1. Room cooling

Room cooling involves exposing the produce to cold air in a refrigerated room to start the cooling process and to remove field heat. Room cooling may be used with most commodities, but may be too slow for produce that requires rapid cooling. If properly designed, a room cooling system can be relatively energy efficient.

Room cooling is very often inadequate for produce stored in large containers, such as bulk boxes or pallet loads. During the room cooling of such large containers of produce, heat is slowly removed from produce positioned near the periphery of the container. Meanwhile at the centre of the container, heat is often generated by natural respiration more rapidly than it can be removed, causing the temperature to rise.

Room cooling is also inadequate for produce requiring rapid and immediate cooling. Strawberries, for example, must be cooled as quickly as possible after harvesting if their quality is to be preserved. Even a delay of several hours may be enough to reduce their quality considerably. Room cooling is not rapid enough to prevent serious damage.

2. Forced-air cooling

Forced-air cooling makes use of fans that increase the rate of cooling in a refrigerated room by pulling cool air through packaged produce, thereby picking up heat and greatly increasing the rate of heat transfer. Although the cooling rate is dependent on the air temperature and the rate of airflow through the packages, this method is usually 75 to 90 per cent more efficient than room cooling

Produce items that can be cooled by forced air include; Coconut, Mango, Prickly pear, Avocado, Cucumber, Melons, Pumpkin, Banana, Eggplant, Okra, Rhubarb, Breadfruit, Grape, Orange, Strawberry, Brussels sprouts, Grapefruit, Papaya, Summer squash, Guava Passion fruit Tangerine Cassava, Kiwifruit, Pepper (Bell), Tomato, Pineapple, Pomegranate, Litchi.

B. Cooling with water

1. Hydro-cooling

Hydro-cooling is appropriate for commodities that are not sensitive to wetting. This cooling process involves the flow of chilled water over the produce, rapidly removing heat. At typical flow rates and temperature differences, water removes heat about 15 times faster than air. Hydro-cooling is only about 20-40 per cent energy efficient, as compared to 70 or 80 per cent for room and forced-air cooling, respectively.

During hydro-cooling, the produce comes into contact with water. Good water sanitation practices must, therefore, be observed during the hydro-cooling process in order to minimize contamination. Once cooled, the produce must be kept cold.

Produce packaged in wire-bound wooden crates, waxed fibre board cartons, mesh poly bags and bulk bins can be hydro-cooled. Palletised packages can be hydro-cooled if they are carefully stacked to allow water to enter the packages. If the water flows around and not through the packages, little cooling will occur. Produce in waxed cardboard cartons with solid tops is particularly difficult to cool since the tops preclude the entry of water. Table 2 shows a range of commodities that can be subjected to hydro-cooling.

Produce that can be hydro-cooled are; Artichoke, Celery, Peas, Asparagus, Chinese cabbage, Pomegranate, Beet, Cucumber, Rhubarb, Broccoli, Eggplant, Radish, Brussels sprouts, Green onions, Spinach, Cantaloupe, Kiwifruit, Summer squash, Carrot, Leek, Sweet corn, Cassava, Orange, Swiss chard, Cauliflower, Parsley.

2. Cooling by contact with ice

Icing is particularly effective on dense packages that cannot be cooled with forced air. Ice removes heat rapidly when first applied to produce but, unlike other cooling methods, continues to absorb heat as it melts. Because of this residual effect, icing works well with commodities such as broccoli that have high respiration rates. Icing is relatively energy efficient. One pound of ice will cool about three pounds of produce from $29.4^{o}C$ to $4.4^{o}C$. Ice must, however, be free of chemical, physical and biological hazards.

3. Top icing

Top icing is used to cool a variety of commodities. In the top-icing process, crushed ice is added either by hand or machine over the top of the produce.

Crops that can be cooled by top icing: Broccoli. Green onions, Brussels sprouts, Leek, Cantaloupe, Parsley, Carrot, Peas, and Chinese cabbage.

4. Liquid icing

Liquid icing involves injecting a slurry of water and ice into produce packages through vents or handholds without de-palletising the packages or removing their tops. Growers with both small and large operations can use crushed and liquid ice cooling methods effectively. Liquid icing is an excellent cooling method, despite the fact that the produce is wet during the process. The surface of warm, wet produce, however, provides an excellent site for the development of post-harvest diseases.

5. Individual package icing

The simplest method of icing is to manually add a measured amount of crushed ice to the top of each carton filled with produce. This method is sufficient in many instances, but can result in uneven cooling since the ice generally remains in the location where it was placed until it has melted. The process is also slow and labour intensive since each carton must be opened, iced and re-closed. Individual package icing has been automated to some extent by ice-dispensing devices and the use of package conveyors and roller benches. This method of icing is not usually recommended for high-volume production.

6. Packaging containers suited for icing

Many types and sizes of fresh produce containers can be used successfully for package icing. Popular types include waxed fibre board cartons; wooden wire-bound crates, baskets and hampers; and perforated plastic liners. Any container that will retain its strength after wetting can be used satisfactorily for icing. Waxed fibre board cartons are particularly well suited for icing operations. They have minimal openings, offer some insulation to help reduce the rate of melting and their strength is unaffected by wetting.

C. Vacuum cooling

Vacuum cooling is effective on produce having a high ratio of surface area to volume (see table 4). This includes produce items such as leafy greens and lettuce, which would be very difficult to cool with forced air or hydro-cooling. During the vacuum cooling process, the produce is placed inside a large metal cylinder and much of the air is evacuated. The vacuum so created causes water to evaporate rapidly from the surface of the produce, lowering its temperature. The process may cause wilting from water loss if overdone.

Crops that can be vacuum- cooled: Brussels sprouts, Lettuce, Carrot, Peas, Cauliflower, Snap beans, Celery, Spinach, Chinese cabbage, Sweet corn, Leek, Swiss chard.

D. Evaporative cooling

Evaporative cooling is an appropriate, effective and inexpensive means of providing low temperature and high relative humidity conditions for cooling produce. The process involves misting or wetting produce in the presence of a stream of dry air. Evaporative cooling works best when the relative humidity of the air is less than 65 per cent. Produce should be picked during the coolest parts of the day and kept in the shade away from direct sunlight.

E. Appropriate cooling technologies

1. A solar assisted cooling chamber

A solar assisted cooling chamber can be used for temporary storage of fresh fruits at the farm levels. The hollow walls of the chamber, which are made of porous clay bricks, are kept moist by a water source. Evaporation of moisture from the outer surfaces of the walls due to solar energy carried by the wind, results in the drop of the temperature within the chamber by 4-5^{o}C below ambient temperature. The moist walls of the cooler maintain a relative humidity of 85-90 per cent within the chamber. The storage life of fresh fruit stored within the chamber can be prolonged by two to three weeks.

3.2Transportation of crop produce and Factors that may compromise quality during transportation

Transportation facilitates the rapid movement of fresh produce within the horticultural supply chain. Fresh produce must be properly protected during transportation in order to minimize mechanical damage, temperature abuse, taint and contamination by food-borne pathogens. It is the responsibility of the transport provider to ensure that the transport vehicle is well maintained and is in a hygienic condition.

Transportation systems are important in moving fresh produce from production areas to distribution points.

3.2.1 Factors that may compromise quality during transportation

3.2.1.1 Mechanical damage

Mechanical damage of fresh produce results in tissue darkening or colour changes on the skin of the commodity and markedly affects its nutritional and sensory quality, i.e. its taste, texture, appearance and flavour. Mechanical damage can also lead to moisture loss, pathogen invasion and can stimulate the production of ethylene, which triggers the senescence process in horticultural crops such as apples, papayas and tomatoes.

Types of mechanical damage that occur during transportation

Impact damage occurs due to;

• collision between produce items or between produce and hard surfaces;

• rapid acceleration or deceleration, e.g. when fruits are dropped; or

• Exertion or removal of forces (such as impact, compression, vibration and abrasion) within a short time (duration impact).

Impact damage can result in bruising with or without skin injury.

ii. Compression damage

• occurs when produce is subjected to heavy commodity weight, with or without physical movement, as occurs when containers are of inappropriate depth, over-packed, packed in containers of poor structural integrity, improperly packed or stacked too high;

• generally results in distortion cracks and splits;

• is usually caused by package failure; and

• is also caused by stacking or sitting on top of produce.

iii. Abrasion damage

• occurs when the surfaces of produce slide across another surface causing friction;

• can result in removal of the cuticle and wax layers of produce; and

• can be minimized with the use of lining or padding materials, such as paper or sleeves to protect the produce .

iv. Vibration damage

The level of vibration of a moving vehicle is greatly influenced by the nature of the road and the suspension system of that vehicle. Vibration occurs when produce moves repeatedly for prolonged periods within a container during transport. Vibration can result in damage due to compression, impact and abrasion.

v. Vibration damage can be prevented, or limited, by the following practices:

• Use plastic crates for transportation – vibration damage is less with plastic crates than with cartons since plastic crates absorb and dissipate the force, thereby keeping the effects of vibration within the crate.

• Use rigid containers to limit the movement of the base of the container in the transport vehicle.

• Use a vehicle with a firm suspension system.

• Use radial tires, which absorb more impact than other types for road transport.

vi. Minimizing mechanical damage

Mechanical damage can be minimized through the use of packaging that can withstand:

• rough handling during loading and unloading;

• compression from the overhead weight of other containers;

• impact and vibration during transportation; and

• high humidity during pre-cooling, transit and storage.

3.2.1.2 Overheating

Overheating occurs due to external sources (such as the sun, heat from the road, the walls of the vehicle etc.) as well as from heat generated by the produce within the transport vehicle. Overheating causes natural breakdown and decay and increases the rate of water loss from the produce. Overheating can, therefore, result in overall quality loss.

i. Factors that contribute to overheating include:

• heat generated by the produce due to respiration;

• lack of ventilation, as occurs in closed vehicles;

• restricted movement of air between and through packages;

• lack of adequate ventilation in packaging; and

• exposure of packaged produce to the sun while waiting to be transported or unloaded.

ii. **Overheating can be avoided by:**

• use of well-ventilated vehicles;

• proper stacking to allow for the disposal of heat;

• use of well-ventilated packaging;

• avoidance of exposure to the sun on loading and off-loading tarmacs; and

• travelling early in the morning or at night if non-refrigerated transport is used.

iii. Loading patterns in transport systems to minimize overheating

Stacking patterns in transport vehicles should minimize contact between the produce and the floor and wall surfaces of the vehicle to reduce the transmission of heat from the outside of the vehicle into the loaded produce.

Centre-loading leaves an insulating air space between the load and the outside walls of the vehicle. Produce transported in cartons should be stacked to allow adequate air circulation throughout the load . The industry norm is to load palletised fruit, i.e. fruit in cartons placed on a pallet. Palletisation makes loading easier and more cost effective than loading loose cartons into the container. Palletising is usually done after other pre-cooling methods, but before forced air-cooling. Pallets must, however, be properly secured by strapping, corner bracing or net wrapping.

3.2.1.3Build- up of gases in the transport system

Inadequate air circulation during the transportation of fresh produce can lead to the build- up of ethylene or carbon dioxide. Care must therefore be taken to assure proper ventilation within the transportation vehicle in order to avoid gas build up.

a) Transportation of mixed loads

Mixed loads can be of serious concern when temperature optima are not compatible or when ethylene-producing commodities and ethylene-sensitive commodities are transported together. Wet and dry produce items must be transported in separate mixed loads in order to avoid the transfer of contamination from wet to dry produce.

3.2.2Hygiene in transport systems

The quality of perishable produce can be adversely affected by a lack of standard hygiene in transportation systems. Soil, typically found in a field, can encrust the floor area of the transport system. In order to prevent contamination by food-borne pathogens, transport systems should make use of good sanitation practices, ensure proper temperature and humidity management and minimize potential damage to the produce. It is critical that all vehicles used for transportation of food products are cleaned and washed routinely to remove decaying remains of agricultural produce. Water, used for washing, must be safe and clean. If pallets are cleaned by fumigation, only recommended/permitted fumigants or chemicals must be used and such use must be according to the manufacturers' recommendations.

3.2.3 Factors that govern the selection of the mode of transportation

The mode of transportation is influenced by:

- The destination of the produce
- The value of the produce
- The degree of perishability
- The volume of produce to be transported
- Recommended storage temperature and relative humidity conditions for the load
- Ambient temperature conditions at origin and destination points
- Time in transit to reach the destination by air, land or sea transport
- Road access
- Freight rates
- Quality of the transportation service

3.2.3Transport equipment

Equipment used for the transport of fresh produce includes:

- Refrigerated and non-refrigerated vehicles – for highway transport
- Containers for air, rail and highway transport, and for lift-on/lift-off ocean transport
- Break bulk refrigerated vessels – for handling palletised loads in the refrigerated holds of vessels
- Pallets – for air cargo and highway transport
- Horse carts, donkeys
- Wheelbarrows and carts – for transportation over distances of 1-8km

Refrigerated and non-refrigerated vehicles

Refrigerated or non-refrigerated vehicles can be used for the bulk transportation of fresh produce.

i. Non-refrigerated vehicles

Non-refrigerated vehicles must provide sufficient cooling of the produce during transport. The load should be covered with a white/light-coloured canvas to avoid overheating and to allow adequate air circulation throughout the produce.

A truck-ventilating device, can be used to facilitate airflow in non-refrigerated trucks consists of wind catchers and ducts, which are constructed using wooden crates or galvanized iron. The open-ended crates are wired together into a sturdy pattern. Air flows upwards through the load during transport, so avoiding extensive overheating of the produce. Best results can be obtained if produce is transported during the early morning hours before sunrise.

ii. Refrigerated trailers

Refrigerated vehicles/trailers must be properly insulated, have a high-capacity refrigeration unit and fan and an air-delivery duct. The vehicle should be well insulated to maintain a cool environment for pre-cooled commodities and adequately ventilated to allow air movement through the produce.

iii. Containers

Containers are insulated metal boxes that are designed for the transport of large volumes of produce over long distances. They are generally equipped with thermometers and/or data loggers, which measure discharge air temperature at their specific locations and provide performance records of the operation of the refrigeration unit.

iv. Refrigerated containers

Refrigerated or reefer containers are generally equipped with a cooling unit, and require an external source of electricity to power the cooling unit and air circulation fans. Reefer containers are available in both 6.1 m and12.2 m lengths. The 12.2 m reefer container is the most commonly used in the fruit export industry worldwide. The 6.1 m container is generally considered a relatively expensive option when compared to the 12.2m container.

Modern containers incorporate microprocessors and computers for controlling the refrigeration system. The 40-foot standard container can usually accommodate 20 ISO (International Organization of Standardization) pallets, while the 20-footer can accommodate nine pallets.

v. Porthole containers

Porthole containers are insulated containers in which cold air is supplied by an external cooler at the required temperature. The warm air within the porthole container is extracted from the top of the load. Air flows to and from the porthole container via vents or portholes.

vi. Controlled atmosphere (CA) containers

Controlled atmosphere containers are designed to maintain the composition of the storage atmosphere around fruits within the container

Categories of CA containers:

• Refrigerated – here the containers are fitted with special equipment to maintain controlled atmosphere (CA) conditions.

• Add-on – here containers have the basic controls fitted in the refrigeration unit, but require the addition of gas and chemicals to establish and maintain CA conditions.

• Central system containers – these containers have basic fittings that need to be connected to a central plant on board the ship to establish and maintain CA conditions.

vii. Break bulk refrigerated vessels

Break bulk refrigerated vessels consist of a number of cold rooms, which can accommodate palletised produce. Between 140 and 400 pallets per cold room can be accommodated in break bulk refrigerated vessels.

viii. Palletisation

The palletisation of produce facilitates handling during shipping. Palletisation reduces damage to produce and increases the efficiency of loading and unloading operations. Plastic netting of palletised loads helps in preventing vibration and impact damage to the produce during transit.

3.3 Packing and Packaging of fresh produce

The longer the distance between the producer and the market, the greater is the cost of marketing and the requirement for proper packaging to minimize injury to produce. This section discusses packing and packaging materials and techniques that ensure produce integrity and quality.

Packing is the act of arranging or organizing produce. Perishable produce may be packed on the farm where it is produced, or can be moved to another location such as a co-operative or pack house for packing. Careful handling is crucial during packing to ensure produce integrity and to maintain quality. Packing can greatly influence airflow rates around a commodity, thereby affecting its temperature and relative humidity while in transit. Produce may be either packed by hand or by using a mechanical packing system.

Packaging is a coordinated system of preparing goods for safe, secure, efficient, and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal combined with maximizing consumer value and hence profit.

3.3.1 Requirements of Packaging

The package must stand up to long distance transportation, multiple handling, and the climate changes of different storage places, transport methods and market conditions. In designing fruit packages one should consider both the physiological characteristics of the fruit as well as the whole distribution network.

The package must be capable of;

- Protecting the product from the transport hazards.
- Preventing the microbial and insect damage and
- Minimizing the physiological and biochemical changes and losses in weight.

The present packaging systems for fresh vegetables in Nigeria is unsuitable and unscientific. The uses of traditional forms of packages like bamboo baskets are still prevalent. The other types of packages generally used are wooden boxes and gunnysacks. The use of corrugated fiberboard boxes is limited. The use of baskets besides being unhygienic also does not allow adequate aeration and convenience of easy handling and stocking. Considering the long term needs of eco-systems and to achieve an overall economy, other alternatives available like corrugated fibre board boxes, corrugated polypropylene board boxes, plastic trays / crates / wooden sacks, molded pulp trays / thermoformed plastic trays and stretched film and shrink wrapping would have to be considered.

Modern packages for fresh fruits and vegetables are expected to meet a wide range of requirements, which may be summarized as follows.

i. The packages must have sufficient mechanical strength to protect the contents during handling, transport and while sacked.
ii. The construction material must not contain chemicals, which would transfer to the produce and cause toxic to it or to humans.
iii. The package must meet handling and marketing in terms of weight, size and shape.
iv. The packages should allow rapid coding of the contents.
v. The security of the package or its ease of opening and closing might be important in some marketing situations.
vi. The package should identify its contents.
vii. The package must be required to aid retail presentation.

viii. The package might need to be designed for ease of disposal, reuse or recycling.
ix. The cost of the package should be as less as possible.
x. Packaging may or may not delay or prevent fresh fruits and vegetables from spoiling. However, incorrect packaging will accelerate spoilage.
xi. Packaging should serve to protect against contamination, damage and excess moisture loss.

3.3.2The characteristics of packaging

The characteristics of packaging are to contain, to protect, to communicate and to market the product.

A. To contain produce:

- As an efficient handling unit, easy to be handled by one person.
- As a marketable unit. e.g. units with the same content and weight.

B. To protect produce against:

- Rough handling during loading, unloading and transport - rigid crate.
- Pressure during stacking.
- Moisture or water loss with consequent weight and appearance loss.
- Heat: air flow through crate or box via ventilation holes.
- Fumigation possible through ventilation holes.

C. To communicate:

- Identification: a label with country of origin, volume, type or variety of product, etc. printed on it.
- Marketing, advertising: recognizable trade name and trademark.

D. To market the product:

- Proper packaging will lead to reduced injuries of fruits and vegetables and subsequently to improvement of appearance.
- Standard units (weight, count) of a certain produce will increase speed and efficiency of marketing.

- With reduced costs of transport and handling, stacking and combining of packages into layer units like pallets is possible. A more efficient use of space and reduced losses will lower the marketing costs.
- Labels and slots facilitate inspection.

3.3.3 Role of Packaging in Preventing Mechanical Damage.

The four main types of mechanical damage are cuts, compression bruises, impact damage and vibration rubbing.

- **Cuts:** Care in harvesting and handling will help eliminate cuts and wounds. Lining of packaging with paper or leaves can also prevent damage to the contents.
- **Compression bruises:** These can be reduced by using containers that are strong enough to withstand multiple stacking. The packaging materials need to be particularly strong at the vertical corners. The packaging should also be shallow enough to prevent the bottom layers of produce from being damaged by the weight of produce above. Cartons must not be overfilled or damage will be caused by the full weight of the pile of produce pushing down on the top layer of fruit or vegetables, causing the weight to be transmitted to the lower layers.
- **Impact damage:**. Shocks in transport or dropping of containers can result in this kind of damage. Dropping may occur either because a package is small enough to be thrown or because it is too big to be easily handled. A packing unit should not exceed 50 kg as this is the maximum weight that can be easily handled. Package size specifications usually depend on the customers' requirements, although in many countries the supply of good packaging materials is limited and buyers may have to accept what is available.
- **Vibration rubbing:** This kind of damage generally occurs during transport. It can be significantly reduced by preventing the produce from moving within the packaging while, at the same time, ensuring that fruits or vegetables are not forced together. Fruits can be prevented from rubbing against one another by the use of cellular trays, individual wraps or cushioning pads. An example is the use of paper and straw to separate layers of apples. An alternative approach is for the container to be gently shaken, in order to settle the produce, with the space created then being filled.

Packing materials can act as vapor barriers and can help maintain higher relative humidity within the package. In addition to protection, packaging allows quick handling throughout distribution and marketing and can minimize impacts of rough handling.

3.3.4Packaging Materials

Packaging can be the single most expensive cost, particularly with non-returnable containers made of wood or cardboard. The benefits of packaging must clearly justify the investment. A great variety of materials are used for the packing of perishable commodities. They include wood, bamboo, rigid and foam plastic, solid cardboard and corrugated fibre board. The kind of material or structure adopted depends on the method of perforation, the distance to its destination, the value of the product and the requirement of the market.

1. CFBC Boxes

Corrugated fiberboard is the most widely used material for fruit & vegetable packages because of the following characteristics:

i. Light in weight

ii. Reasonably strong

iii. Flexibility of shape and size

iv. Easy to store and use

v. Good pointing capability

vi .Economical

2. Wooden Boxes

Materials used for manufacture of wooden boxes include natural wood and industrially manufactured wood based sheet materials.

3. Sacks

Sacks are traditionally made from jute fibre or similar natural materials. Most jute sacks are provided in a plain weave. For one tonne transportation of vegetables, materials of 250 grams per square meter or less are used. Natural fibre sacks have in many cases been replaced by sacks made of synthetic materials and paper due to cost factors, appearance, mechanical properties and risk of infestation and spreading of insects. Sacks made of polypropylene of type plain weave are extensively used for root vegetables. The most common fabric weight is 70-80 grams per square meter.

4. Palletisation

Pallets are widely used for the transport of fruit and vegetable packages in developed countries.

The advantages of handling packages on pallets are:

i. Labour cost in handling is greatly reduced

ii. Transport cost is reduced.

iii. Goods are protected and damage reduced.

iv. Mechanized handling is very rapid.

v. Through high stacking, storage space can be more efficiently used.

vi. Pallets encourage the introduction of standard package sizes.

5.Packaging films

The packaging industry has become increasingly responsive to the specific gas requirements of fresh produce and is now providing films tailored to the requirements of given types of fresh produce. Films are available for commodities having low, medium and high respiration rates. The oxygen transmission rates of the films are matched to the minimum level of O_2 required for the produce to retain its quality.

6. Modified atmosphere packaging films

Modified atmosphere packaging (MAP) employs packaging films to manipulate the respiration rates of fresh produce and thereby extend shelf life. MAP makes use of the carbon dioxide produced by respiration and oxygen consumed during the respiration process, for the production of an environment within the package that slows the metabolic activity of the produce. The goal of MAP is to create an equilibrium atmosphere, such that the oxygen concentration is adequately low and the carbon dioxide concentration is adequately high, to be beneficial and not injurious to the produce.

Packaging films such as low density polyethylene, which can be easily sealed and offer good permeability to O_2 and CO_2, are durable at low temperatures and which have good tearing resistance, are appropriate in use for MAP. MAP films can be impregnated with minerals in order to absorb and remove ethylene produced in the storage environment around the bagged produce. Impregnated MAP films are particularly suitable for transporting bulk fresh fruit and vegetables to distant markets or between farmers and consumers at supermarkets and retail outlets.

Produce contained in MAP must be maintained under appropriate temperature conditions and must be properly handled and packaged prior to transport if freshness is to be maintained, shelf life extended and safety assured. Neither low temperature nor MAP can act alone to deliver full value to the consumer, the reason being that both factors work together to slow the metabolism and aging of the produce thereby extending the shelf life and maintaining the quality.

3.3.5 Key considerations when selecting packaging materials suitable for fresh produce

• **Container dimensions –** Containers must be of the appropriate weight and measurements. They can be altered to suit the needs of the handler and the produce item. For example, tomato boxes must be 39cm long and 25cm wide, with 3.5cm raised corners such as triangular corner supports to increase the strength of the carton.

• **Ventilation –** Fresh-air exchange helps prevent unwanted ripening and the accumulation of odours, and ensures longer shelf life for many perishables. Holes within the packaging facilitate both horizontal and vertical airflow, thereby facilitating cooling of the produce. Temperature management can be difficult if packing materials block ventilation holes

• **Ease of handling –** The weight and size of boxes must facilitate easy handling.

• **Compliance with standard design and marketing demand –** The specific packaging requirements of buyers must be taken into account during the selection of packaging materials. Many supermarket chains differentiate themselves from others through unique packing or branding. Chemicals that are banned in certain importing countries may not be used in packaging. In fact, a number of importing countries now stipulate that packaging must be recyclable and must clearly identify the product and its origin so that it can be traced back to its source.

Packaging material design must include holes (5 per cent) for ventilation

- **Ease of palletisation –** cartons are the primary form of outer packaging used for the international export of fruit. Pallets provide a strong base for transporting and storing cartons that weigh up to 1 tonne. The stacking pattern of palletised cartons is dependent on the height of the carton and the positioning of the ventilation holes. Pallets must be constructed from environmentally friendly materials and must comply with the standards of the exporting and importing countries. Effective as of 2005, all packaging material made of wood must be either heat- or chemically-treated to comply with international standards.

- **The following basic care must be taken during palletisation:**
  - **Surface finish –** the surface of the package must be smooth in order to prevent damage to the produce
  -**Easy of cleaning –** packaging must be easily cleaned if it is to be re-used

3.3.6 Packaging materials for produce destined for local markets

Woven plastic packaging provide the following advantages;

• withstands impact;

• provides protection against insects if closely woven;

• is somewhat effective in preventing contamination; and

• does not absorb moisture.

Advantage of fibre board is;

• provision of some protection against insects.

Advantages of plastic crates are;

• withstand impact during transportation;

• can be easily be stacked and palletized;

• offer some protection against contamination.

Jute bags have the following advantages;

• provide good protection against impact damage;

• do not absorb moisture;

• are biodegradable; and

• retain produce odour.

Corrugated cardboard boxes

• withstand impact forces and localise the produce;

• if they are waxed, provide protection against moisture and humid environments;

• contribute to prevention of produce contamination; and

• are stackable and can be palletised during transportation.

3.3.7 Packaging materials for produce destined for long-distance and export markets

Bulk bins

Bulk bins (1000 x 1200mm), which are capable of carrying 300kg of fruit, are used for the export of produce items such as oranges for juicing. Bulk bins can be stacked on top of each other and fastened with securing strips. The combined weight of the bins must be less than 100 kg

Cartons

Fruit cartons made from corrugated cardboard, polystyrene and polypropylene are used for the export of fresh produce. The packaging container must comply with standards set by the exporting and importing country. Cartons must be strong enough to bear the weight of the produce, must either be waxed or should not absorb moisture easily and should be adequately ventilated so as to allow horizontal and vertical airflow.

The number of cartons stacked on a pallet is dependent on the size and depth of the cartons. For example, a total of 75 cartons measuring 600 x 400 x 120mm can be stacked on a 2.1m pallet, while 260 cartons measuring 400 x 300 x 70 mm can be accommodated on a pallet stacked to a similar height.

Each carton may contain fruit packaged in small units or secondary packaging units such as fruit wrappers, plastic bags, nettings or pun nets. Nets offer the advantage of allowing the fruit to breathe freely. Pun nets are generally made of polypropylene or polyethylene and are used for the packaging of small fruits such as plums, apricots and grapes. Some buyers require that grapes be packed in polycot, carry or ‘zips lock’ bags.

3.3.8 Labeling

Labeling helps handlers to keep track of the produce as it moves through the horticultural supply chain. Labeling assists the wholesale agents and retailers in using proper practices. Labels are pre-printed or glued, stamped or stenciled on to the packaging container.

The label must mention the following:

- count, cultivar, class type or size;
- weight;
- producer’s code;

• pack house code;

• name and address of the exporting packer;

• country of origin;

• any special treatment given e.g. SO_2 fumigation or type of approved wax or pesticides used etc.; and

• recommended storage temperature and special handling instructions.

3.3.9 Types of Packages

3.3.9.1.Controlled and Modified Atmospheric Packaging (CAP and MAP)

The normal composition of air is 78% Nitrogen (N), 21% Oxygen (O_2), 0.03% Carbon dioxide (CO_2) and traces of other noble gases. Modified atmosphere packaging is the method for extending the shelf-life of perishable and semi-perishable food products by altering the relative proportions of atmospheric gases that surround the produce. Although the terms Controlled Atmosphere (CA) and Modified Atmosphere (MA) are often used interchangeably a precise difference exists between these two terms.

3.3.9.2 Controlled Atmosphere (CA)

This refers to a storage atmosphere that is different from the normal atmosphere in its composition, wherein the component gases are precisely adjusted to specific concentrations and maintained throughout the storage and distribution of the perishable foods. Controlled atmosphere relies on the continuous measurement of the composition of the storage atmosphere and injection of the appropriate gases or gas mixtures into it, if and when needed. Hence, the system requires sophisticated instruments to monitor the gas levels and is therefore practical only for refrigerated bulk storage or shipment of commodities in large containers.

If the composition of atmosphere in CA system is not closely controlled or if the storage atmosphere is accidentally modified, potential benefit can turn into actual disaster. The degree of susceptibility to injury and the specific symptoms vary, not only between cultivars, but even between growing areas for the same cultivars and between years for a given location. With tomatoes, excessively low O_2 or high CO_2 prevents proper ripening even after removal of the fruit to air, and CA enhances the danger of chilling injury. The differences between beneficial and harmful concentrations of oxygen and carbon dioxide for each kind of produce are relatively small, so great care must be taken when using these technologies.

3.3.9.3 Modified Atmospheric Packaging (MAP)

Unlike CAPs, there is no means to control precisely the atmospheric components at a specific concentration in MAP once a package has been hermetically sealed.

Modified atmosphere conditions are created inside the packages by the commodity itself and / or by active modification. Commodity generated or passive MA (Modified Atmosphere) is evolved as a consequence of the commodity's respiration. Active modification involves creating a slight vacuum inside the package and replacing it with a desired mixture of gases, so as to establish desired EMA (Equilibrated Modified Atmosphere) quickly composed to a passively generated EMA.

Another active modification technique is the use of carbon dioxide or ethyl absorbers (scavengers) within the package to prevent the build-up of the particular gas within the package. This method is called active packaging. Compounds like hydrated lime, activated charcoal, magnesium oxide are known to absorb carbon dioxide while iron powder is known as a scavenger to carbon dioxide. Potassium permanganate and phenyl methyl silicone can be used to absorb ethylene within the packages. These scavengers can be held in small sachets within the packages or impregnated in the wrappers or into porous materials like vermiculite. For the actively respiring commodities like fruits and vegetables, the package atmosphere should contain oxygen and carbon dioxide at levels optimum to the particular commodity. In general, MA containing between 2-5% oxygen and 3.8 % CO_2 have shown to extend the shelf life of a wide variety of fruits and vegetables.

If the shelf life of a commodity at 20-25°C is one day, then by employing MAP, it will get doubled, whereas refrigeration can extend the shelf life to 3, and refrigeration combined with MAP can increase it to four days. Few types of films are routinely used for MAP. The important ones are polyvinyl chloride, (PVC), polystyrene, (PS), polyethylene (PE) and polypropylene (PP). The recent developments in co-extrusion technology have made it possible to manufacture films with designed transmission rates of oxygen.

3.3.9.4 Vacuum packaging

Vacuum packaging offers an extensive barrier against corrosion, oxidation, moisture, drying out, dirt, attraction of dust by electric charge, ultra violet rays and mechanical damages, fungus growth or perishability etc. This technology has commendable relevance for tropical countries with high atmospheric humidity.

In vacuum packaging, the product to be packed is put in a vacuum bag (made of special, hermetic fills) that is then evacuated in a vacuum chamber and then sealed hermetically in order to provide a total barrier against air and moisture. If some of the product cannot bear the atmospheric pressure due to vacuum inside the package then the packages are flushed with inert gases like Nitrogen and CO_2 after evacuation.

3.3.9.5 Edible Packaging

An edible film or coating is simply defined as a thin continuous layer of edible material formed on, placed on, or between the foods or food components. The package is an integral part of the food, which can be eaten as a part of the whole food product. Selection of material for use in edible packaging is based on its properties to act as barrier to moisture and gases, mechanical strength, physical properties, and resistance to microbial growth. The types of materials used for edible packaging include lipids, proteins and polysaccharides or a combination of any two or all of these. Many lipid compounds, such as animal and vegetable fats, acetoglycerides have been used in the formulation of edible packaging for fresh produces because of their excellent moisture barrier properties. Lipid coatings on fresh fruits and vegetables reduce weight losses due to dehydration during storage by 40-70 per cent. Research and development effort is required to develop edible films and coatings that have good packaging performance besides being economical.

3.3.10 Packing techniques

Packing techniques must ensure that:

• Produce is correctly arranged within the packaging material to reduce the risk of damage;

• Produce is not damaged by wounding during the packing process – for example, by micro-wounding because of nails sticking into the produce, thereby creating an ecological niche for microbial infection; and

• Hygienic conditions are maintained – contaminated hands or contaminated containers may transfer food-borne pathogens to the produce. Fresh produce packers must observe high levels of personal hygiene: gloves can be worn during packing, but should be washed at regular intervals to prevent them from becoming a trap for food-borne pathogens.

Packing must also be done against a tight time schedule to ensure that produce can be moved efficiently through the supply chain.

3.3.11 Procedures to make packages more effective

i. Ventilation of Packages

Reduction of moisture loss from the product is a principal requirement of limited permeability packaging materials. A solution to moisture loss problems from produce appeared with the development and wide distribution of semi permeable plastic films. Airflow through the ventilation holes allows hot fruit or vegetable to slowly cool and avoid the buildup of heat produced by the commodity in respiration. Holes are also important in cooling the fruit when the packages are placed in a cold storage, especially with forced air-cooling. Ventilation holes improve the dispersal of ethylene produced.

ii. Cushioning Materials

The function of cushioning materials is to fix the commodities inside the packages and prevent them from mixing about in relation to each other and the package itself, when there is a vibration or impact. Some cushioning materials can also provide packages with additional stacking strength. The cushioning materials used vary with the commodity and may be made of wrapping papers, fibre board (single or double wall), molded paper pulp trays, molded foam polystyrene trays, molded plastic trays, foam plastic sheet, plastic bubble pads, fine shredded wood, plastic film liners or bags.

iii. Throughout the entire handling system, packaging can be both an aid and a hindrance to obtaining maximum storage life and quality. Packages need to be vented yet be sturdy enough to prevent collapse. If produce is packed for ease of handling, waxed cartons, wooden crates or rigid plastic containers are preferable to bags or open baskets, since bags and baskets provide no protection to the produce when stacked.

iv. Containers should not be filled either too loosely or too tightly for best results. Loose products may vibrate against others and cause bruising, while over-packing results in compression bruising. Shredded newspaper is inexpensive and a lightweight filler for shipping container

1. Ethylene absorber sachets placed into containers with ethylene sensitive produce can reduce the rate of ripening of fruits, de-greening of vegetables or floral wilting.

3.4 Handling at whole sale and retail outlet

When handling produce at its destination, the following should be observed

- it is important to avoid rough handling,
- minimize the number of handling steps, and
- maintain the lowest feasible temperature.
- If produce is to be stored before sale, then wholesale and retail markets need clean, well insulated storage rooms.
- it is important to remember not to mix those with different temperature requirements
- or store ethylene sensitive commodities near ethylene generating commodities.
- Stacking of non-uniform containers should be done with care to prevent collapse of weaker packages.
- Before produce is sold to the consumer, the handler may wish to sort for quality, or at least to discard any damaged or decayed produce in order to give the product more market appeal.
- If ripeness or maturity is non-uniform, sorting at destination can provide the seller with a higher price for the better quality produce.
- If the produce handled is a climacteric fruit crop that was harvested before it was ripe(bananas, tomatoes, avocadoes, mangoes), the handler at destination may want to ripen the produce before it is sold to the public. Sometimes commodities such as bananas are left at ambient temperatures and allowed to ripen naturally. Covering the bananas with a plastic sheet will help ripening be more uniform throughout the lot
- Placing a simple air vent (a pipe or a tube of some sort) into the center of the pile of ripening fruit can help reduce overheating during ripening and increase subsequent shelf life.

- The introduction of ethylene gas or ethylene-releasing compounds into a special storage environment (known as a ripening room or cabinet, depending upon size) is a more effective way to ensure uniform ripening.
- Temperatures of the display tables or refrigerated supermarket displays should be suited to the commodity on sale. For example, while peppers and tomatoes look pleasing when displayed with lettuce, peppers and tomatoes are chilling sensitive, while lettuce is not.
- Misting commodities that can tolerate surface water (lettuce, broccoli, green onions) with cool clean water can help maintain a high relative humidity around the product.
- Outdoor marketplaces suffer from a lack of temperature control and high air circulation, which can lead to desiccation of crops, which will be seen as shriveling and wilting. These marketplaces can often benefit by the increased use of shading and protection from prevailing winds.

Finally, the handler at destination can help reduce losses in the future by maintaining good records of the sources of losses suffered at the wholesale or retail level. Identifying whether losses were due to mechanical damage, decay/disease, immaturity or over-ripeness allows the handler to provide better quality feedback to produce suppliers.

Unloading

A loading dock can ease the work associated with handling horticultural produce at destination. Containers can be transferred more rapidly and with less bending and lifting.

For large trucks, a loading dock 117 to 122 cm high (46 to 48 inches) functions well, while for small trucks or pickups a height of 66 to 81 cm (26 to 32 inches) is recommended.

A simple set of stairs can be constructed to ease the work of loading and unloading produce. Providing hand-trucks or small carts can also ease the work associated with unloading.

Temporary storage temperatures

When produce is held at destination for a short time before marketing, the handler can help maintain quality and reduce losses by storing commodities at their most suitable temperature. However, if the storage period is seven days or less, relative humidity is maintained between 85 and 95%, and the ethylene level is kept below 1ppm, by ventilating or using a scrubber.

Sorting/repacking

Some produce may require washing, trimming, bunching or sorting at the wholesale or retail market level. The layout of the work station used for handling produce at destination should be organized to minimize non-productive movement. In the illustration below, a dump table is located next to a sink for washing produce, and the drain board is positioned directly next to the sink. Once produce has dried, cartons can be packed and placed onto a cart located right next to the repacking table. With this layout, a single operator could easily perform all the handling steps or several handlers could work side by side.

Some produce may have to be repacked by the wholesaler or retailer due to changes in quality or uneven ripening. The tomato sorting table illustrated below has workstations for up to five who select ripe, pinks or breakers and allow the green tomatoes to run off to the end of the line. Rejects (culls) are placed in pails under the table.

Ripening

Ripening is the process by which fruits attain their desirable flavor, color and textural properties. **Climacteric fruits can ripen off the plant** once they have reached physiological maturity. **Climacteric** fruits include apples, avocado, banana, blueberries, breadfruit, cherimoya, durian, feijoa, fig, guava, kiwifruit, mango, muskmelon, papaya, passion fruit, pears, persimmon, plantain, quince, sapodilla, sapote, sour sop, stone fruits(apricots, nectarines, peaches, plums) and tomato. Some of these fruits if harvested "mature-green", can be ripened after harvest and short term storage. Pears and bananas are unusual in that they develop the best flavor and texture characteristics when harvested mature-green and ripened off the tree. Avocadoes do not ripen on the tree.

Some climacteric fruits give off large quantities of ethylene during ripening. These include apples, apricots, avocadoes, cantaloupe, kiwifruit, nectarines, peaches, pears, plums and passion fruit. A small dose of ethylene gas will stimulate other climacteric fruits to begin the ripening process. A few climacteric fruits, such as musk melons, will not increase in sugar content during ripening, but will soften.

Non-climacteric fruits must ripen on the plant if you want a fully ripe fruit, since once they have been harvested, no further ripening will occur. Flavour and texture will be of low quality if fruits are picked before fully ripe. Some **non-climacteric** fruits include berries, cherries, citrus fruits (lemons, limes, oranges, grapefruits, mandarins, tangerines), cucumber, dates, eggplant, grapes, lychee, okra, peas, peppers, pineapple, pomegranates, strawberry, summer squash, tamarillo and watermelon.

Non-climacteric fruits will not respond to attempts to ripen them with ethylene gas. A partially red strawberry, for example, will not develop any more color or sweetness after being picked, and will deteriorate faster if exposed to ethylene. Watermelons develop most of their sweetness during the week before they reach full maturity, making early harvest very undesirable.

Sometimes ripening commodities before sale at the wholesale or retail level will improve their value. Ripening rooms are often used for tomatoes, citrus fruits and bananas. The use of diluted ethylene gas mixtures is safer than using pure ethylene which is explosive and flammable at concentrations of 3% or higher. For tomatoes, technical grade ethylene gas is introduced into the room at a concentration of about 100 ppm for about 48 hours. A small fan can be used to ensure a uniform continuous flow of ethylene into and through the room. Forced-air ripening is increasingly being used to provide more uniform temperatures and ethylene concentrations throughout the ripening room.

Small-scale wholesalers and retailers can ripen fruits in bins or large cartons by placing a small quantity of ethylene-generating produce such as ripe bananas in with the produce to be ripened. Cover the bin or carton with a plastic sheet for 24 hours, and then remove the plastic cover. A simple way to ripen fruits at home in small amounts is to use a ripening bowl. Fruits that require ripening should be placed into the bowl with a ripe apple or ripe banana (or any other high ethylene-generating product). Using this method, ripening will take from one to four days. Home ripening is also possible using another, extremely low-tech practice place fruits to be ripened into a paper bag with a ripe piece of fruit, close loosely and check in a few days.

3.5Display

This wooden display table is designed to be used for commodities such as cruciferous crops or leafy green vegetables that tolerate cooling with ice. The table can be used in the horizontal position or as a tilted display. Crushed ice is required for cooling and a catch pail should be provided for melt water. To minimize ice needs, the display tray should be insulated and kept out of the direct sun. When displaying horticultural crops, single or double layers of produce are most likely to protect the commodities from compression damage and over-handling by the consumers.

High relative humidity can be maintained during display by misting leafy vegetables and water tolerant crops with clean, cold water. A simple sprinkler device can be constructed by perforating a pipe with tiny holes and connecting it to a hose. If this display is used outdoors, shade should be provided. Displays and storage areas must be cleaned and sanitized on a regular basis. Trimmings, waste, and bruised product remaining in displays are unsightly and can be sources of decay, odor and ethylene.

4.0Conclusion

If produce is to be stored, it is important to begin with a high quality product Produce can be stored for both short-term and long-term purposes. Short-term storage is mainly used to provide flexibility in marketing (e.g. when awaiting transport), or because buyers are not immediately available. The lot of produce must not contain damaged or diseased units, and containers must be well ventilated and strong enough to withstand stacking. In general, proper storage practices include temperature control, relative humidity control, air circulation and maintenance of space between containers for adequate ventilation, and avoiding incompatible product mixes. Commodities stored together should be capable of tolerating the same temperature, relative humidity and level of ethylene in the storage environment. The choice of cooling methods is dependent on a number of considerations:
Nature of the produce, Package design, Product flow capacity, Economic factors and Social factors. Factors that may compromise quality during transportation; Are Mechanical damage, Overheating and Buildup of gases in the transport system
Packaging is a coordinated system of preparing goods for safe, secure, efficient, and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal combined with maximizing consumer value and hence profit.

5.0 Summary

In this unit we have studied the conditions of crop storage, controlled atmosphere store, cooling in storage, factors that may reduce quality of produce during storage, hygiene in transportation, Packaging for Fruits and Vegetables and how the new technology and applications used to bring fresh, safe, nutritious produce to the consumer were explained. It explains Modified Atmosphere Packaging (MAP) and its use in packaging fruits and vegetables; it includes variations and advances on MAP such as high vapor-permeable films, and demonstrates modeling techniques to assist in the prediction and selection of packaging type and materials for packaging

6.0Tutor Marked Assignment (TMA)

a. Explain the conditions of storage of crop produce
b. State the importance of packaging
c. Describe the important measures to be observed when handling produce at its destination
d. Describe the factors that may compromise quality during transportation
e. Explain the major considerations when selecting packaging materials suited to fresh produce
f. State the Importance of pre-cooling in the storage of crop produce
g. Describe packaging materials for local markets
h. Describe packaging materials for produce destine for foreign markets
i. Describe handling practices at whole sale and retail outlets

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MODULE 5: DESIGN AND OPERATION OF EQUIPMENT FOR STORAGE AND PRESERVATION

UNIT 1: Designing of Modern Storage Structures

UNIT 2: Equipment for Produce Storage and Preservation

Unit 1: Designing of Modern Storage Structures

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1.0 Introduction

Grain storage structures help protect against crop losses from insects, rodents, moulds, theft, and fire, traditional designs are not always effective, and building them is difficult for poor communities where the hardwood supply is limited due to deforestation.

2.0Objectives

At the end of this unit you should be able to:

- Describe the basic requirements and recommendations for the design of storage structures
- Describe on farm storage structures
- Design modern storage structures

3.0 Designing of Modern Storage Structures

Modern structures should be designed such that they meet certain basicrequirements with regards to location, accessibility and use. The following is a basic guide on the requirements of modern storage structures and systems.

3.1 Basic Requirements and Recommendations for Storage Structures

1. Store site

- Should be easily accessible throughout the year.
- should be sited above flood plains and should not be liable to flooding and the area must have good water drainage.
- Sufficient space to maneuver delivery or collection vehicles

2. Floors

- Floors should be above ground level with sufficient elevation to allow drainage
- They should be crack-free reinforced concrete
- There should be vapour proof barrier under the floor and up to the walls to prevent dampness rising in the walls from the ground

3. Walls

- The inside surface must be plastered with cement/sand and mortar (essential for cleaning and pest control)
- The outside surface must be plastered with cement, lime and sand (helps in keeping the store cool and easy to clean)
- The walls should have windows or openings for ventilation designed not to allow birds or rats to enter
- They should have at least two doors wide enough to allow loading in and out.
- Painting the bins and or walls white (both inside and outside) can reduce the heat absorption by the walls and this can lower temperatures by up to 5 degrees and makes observing insect infestation easier.

4. Roof

- The roof must not have any holes of leaks
- Must be designed to shed water quickly without leaking
- Must keep out pest like rodents, birds, insects, dust and heat

- Roof overhang at eaves level should be sufficient to shed rainwater clear of walls and help to keep the walls cool
- Gutters and draining pipes are not always necessary they get blocked and allow rodent entry in not properly managed

5. Doors

- All doors must be secure and rodent proof
- Doors must be large enough to allow for loading in and outand positioned for better inventory management and supplementary ventilation.

6. Ventilation

Proper ventilation is necessary for the reduction of humidity which encourages pest development. Large doors can provide sufficient, controllable ventilation in the absence of eaves-level ventilation in stores that are regularly opened daily when full.

7. Pest Proof

Complete exclusion of pests is difficult but all possible points must be screened with expanded metal mesh with holes not exceeding 6
mm. Windows should also be screened if they are less than 1 m from the ground since rodents can jump this height.

-Granaries and drying platforms should be erected on large stones or platforms (which must be at least 80 cm high)

They should be reinforced with conical rat guards made of 0.50 mm thick steel plate, 25cm in diameter

-Buildings must be protected by ensuring that all the means of access close properly and are made of materials that are resistant to attack. Rodents must be prevented from climbing along the posts, pipes, cables and rails in contact with the building and guards must be fitted to all these possible means of access

8. Hygiene

As with any grain warehouse, the interior should be designed and built to facilitate cleaning platforms, farm stores, communal warehouses On farm storage is designed to handle and store production from the farm and will consists of small to medium structures like drums, cocoons.

3.2 On farm Modern Storage Structures

1. Metal Silos

Metal silos (including recycled oil drums) have emerged as efficient and low cost storage containers for the storage of cereal grains and pulses.

Inaccessible by rodents, efficient against insects, sealed against entry of water, drums make excellent grain containers. However they should be protected from direct sunshine and other sources of heat. To avoid condensation they should be located in shaded and well ventilated places

2. Hermetic Cocoons

A relatively new development is the hermetically sealed bag or cocoon of various sizes (1 – 300 metric ton), which appear to offer good possibilities to store grain in a variety of quantities. These cocoons are being used in Kenya with some success. The hermetic bags work on the principal that grains releases carbon dioxide which rapidly replaces the oxygen in the sealed container. Once oxygen is exhausted, the pests die and fungi cannot spread.

For these sealed units to work effectively, they need to be completely filled quickly and only open when the entire contents have to be used.

3. Farm Stores

Smaller stores are built with timber on a raised platform. The supporting poles should have rodent proof fixtures to prevent rodents from climbing or jumping into the store. Larger stores may be constructed using iron sheeting

or concrete and should meet the following standards:

- The floor of the inside of the store should be above the level of the ground outside (to prevent dampness and rain entering).
- Ideally there should be damp proofing under the floor and in the walls.
- Ventilation points should be placed in the walls – these should be covered with screens to prevent rats, birds and insects entering.
- The store should have a large well-fitting door to allow carrying bags in and out of the store and for allowing good aeration.
- The stores should preferably be built a distance from the residential house so as to avoid fumigants and other storage chemicals filtering into the residential dwellings.

4. **Communal Warehouses**

Where farmers come together in formal groups they often consider establishing communal stores that are managed by a trained store manager.

The individual farmers can consolidate their stocks ready for the market by delivering to the communal store. This arrangement may be the better option for small holder farmers who do not have the capital to put up own stores, have limitations of land available for the store or do not know how to store commodity well for extended periods of time.

These stores work extremely well as bulking centers where large traders come and pickup truck loads of commodity (preferably of the same quality) at one time. The advantage to the big buyer is the reduction in the cost of buying through multiple aggregate traders with their multiplied handling costs.

5. **Flatbed Warehouses**

The majority of warehousing in Eastern Africa entails flatbed warehouses in which the commodities are stored in bags on pallets in large stacks. These warehouses range from 2,000 to over 15,000 tons. Essentially they are larger versions of the communal warehouse. Generally they will have more than one set of doors for access. Any ventilation openings under the eaves should be covered with screens that keep out rodents, birds and insects. Often there will be a separate grading room as well as an office for record keeping.

6. **Open Sacs**

This form of storage has been used successfully in Zimbabwe in the late 80's and early 90's. With proper planning, careful preparation and the right management this form of storage can fill in the gap where there is a huge shortage of storage space. In this form of storage quantities of upwards of 5000 tons can be stored for periods of up to 2 years or more. The other advantages are that the initial investment is very low and local materials can be used in preparing the stacks and the stack can be constructed anywhere, as long as the place is secure and the ground is suitable.

The disadvantages are that it requires good security especially when there is a shortage of grain in the community. It requires trained and experience personnel to construct the stacks and the preservation of quality through pest control. Special bags which are strong and UV protected have to be used and if the grain is to be stored for long periods. The stacks can be constructed with channels to improve ventilation.

7. **Grain Silos**

Silos are an efficient method of storing grain; bulk grain takes less space and can be handled mechanically reducing bagging and handling costs. Recycling grain in silos helps through aeration to reduce potential increases in grain temperature. This is essential in silo management. There are different types of silos of various sizes for storing grain in bulk.

Silos are either constructed from concrete, bricks or sheet metal bolted together. Bolted corrugated steel silo models are becoming popular in most grain producing countries because they are effective and relatively cheap.

The disadvantage of bulk facilities is that in the case of underutilization they cannot be used for other activities.

4.0Conclusion

The storage structures used depend on the construction material available, amount of produce to be stored, the type of produce, prevailing climatic condition of the area, purpose of storage and the resources of the farmer, in particular the availability of labour and capital.

5.0Summary

The storage structures used depend on the construction material available, amount of crop produce, prevailing climatic condition of the area, socio-cultural aspects of storage and the resources of the farmer, in particular the availability of labour and capital. In the humid forest zone yam is stored in a yam barn which is the principal traditional yam storage structure in the major producing areas. Stores offer shelter to the grain, and in addition, hermetic stores by themselves also prevent pest damage. Grains can be stored in sacks of various types on both a small and large scale. For medium- or long-term storage, hermetic sacks may be used when benefits outweigh costs. In other situations, traditional mud stores (as well as more modern plastic or metal silos) may significantly reduce the postharvest Losses of smallholders. Such stores may be hermetic or at least sufficiently sealed to prevent pest access to grain.

6.0Tutor Marked Assessment (TMA)

i. Describe the basic requirements and recommendations for the design of storage structures

ii. List the different types of on farm modern storage structures

iii. Describe how to design hermetic cocoons and metal silos

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Unit 2: Equipment for Produce Storage and Preservation

Table of contents

1.0 Introduction

The storage structures used depend on the construction material available, amount of produce to be stored, the type of produce, prevailing climatic condition of the area, purpose of storage and the resources of the farmer, in particular the availability of labour and capital.

2.0 Objectives

At the end of this unit you should be able to:

- Identify and describe the different kinds of storage structures commonly used in your locality
- Recommend the most appropriate crop produce storage structure considering the environmental factors
- Recommend the most appropriate structure for the storage of cereals, tubers, roots bulbs, vegetables and fruits

3.0 Equipment for produce storage and preservation

3.1 Yam Storage Structures

Yam storage structures from the different ecological zones of Nigeria. The storage structures used depend on the construction material available, amount of tuber produced, prevailing climatic condition of the area, purpose of yam tuber storage, socio-cultural aspects of storage and there sources of the farmer, in particular the availability of labour and capital. In the humid forest zone yam is stored in a yam barn which is the principal traditional yam storage structure in the major producing areas. Barns in the humid forest zone are usually located under the shade and constructed so as to facilitate adequate ventilation while protecting tubers from flooding, direct sunlight and insect attack. There are several designs, but they all consist of a vertical wooden framework to which the tubers are individually attached [fig.1]. Tubers are tied to a rope and hung on horizontal poles 1-2 m high (Figure 1); barns up to 4 m high are not uncommon. Depending on the quantity of tuber to be stored, frames can be 2 m or more in length. The ropes are usually fibrous; in south-eastern Nigeria they are made from the raffia obtained from the top part of the palm wine tree. Many farmers have permanent barns that need annual maintenance during the year's harvest. In these situations, the vertical posts are often made from growing trees which are trimmed periodically. Palm fronds and other materials are used to provide shade. The vegetative growth on the vertical trees also shades the tubers from excessive solar heat and rain

Figure 1.3.5 Typical yam barn in the humid forest zone of Nigeria (individual yams tied to live poles)

The yam barn in the Guinea Savannah zone is constructed from guinea corn stalk, sticks, grass and yam vines (fig.2). The yams are heaped at different positions in the barn. Such barns are constructed every year and are situated near the house under a tree to protect the tuber from excessive heat. At the end of the storage period the barn is burnt down and in December/January a new structure is built for the next harvest. Unlike the humid forest where it is important that the yams are separated to avoid rotting, in drier areas such as Niger State the yams can be stacked into piles in the barn.

Figure.2.3.5 yam barn in guinea savanna

At the onset of the rainy season the yams are transferred to a mud hut or guinea corn storage rhombus to protect them from the rain. Another yam storage structure found in the savanna region is the yam house or yam crib. “Yam houses” have thatched roofs and wooden floors, and the walls are sometimes made simply out of bamboo. They are raised well off the ground with rat guards fitted to the pillars. Yam tubers are stacked carefully inside the crib (Figure 3). Yam is also stored underground in trench or clamp silos. In both methods a pit is excavated and lined with straw or similar material. The tubers are then stored on the layer of straw either horizontally on top of each other or with the tip vertically downwards beside each other. The yams are then covered with straw or similar materials; in some cases a layer of earth is also added.

3.2Grain storage structures

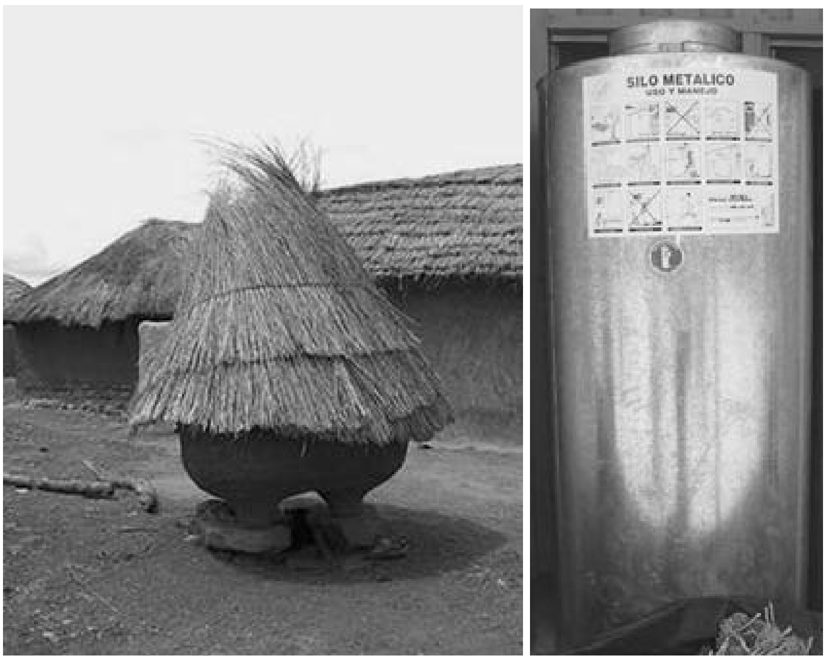
A variety of different storage structures are available according to scale of operation and may either is open to air exchange or airtight (hermetic). Stores offer shelter to the grain, and in addition, hermetic stores by themselves also prevent pest damage. Grains can be stored in sacks of various types on both a small and large scale. For medium- or long-term storage, hermetic sacks may be used when benefits outweigh costs. In other situations, traditional mud stores (as well as more modern plastic or metal silos) may significantly reduce the Post Harvest Losses of smallholders. Such stores may be hermetic or at least sufficiently sealed to prevent pest access to grain.

Adoption of an appropriate and effective method of grain storage can significantly improve the quality and quantity of grain at outturn.

One approach to reducing Post Harvest Losses during storage is either by modifying existing store types so that they perform better or by introducing existing traditional but more effective store types to those communities that *do not already use them* (for example, mud silos). Mud silos (Figure 4.3.5) they offer potential for the better storage of food grains than more open store types can offer, as they are well sealed. Survey work by Opportunity Industrialization Centre, Tamale, has demonstrated that Post Harvest Losses for grain stored in them remain low regardless of whether the crop was treated with a grain storage pest. Modified farm stores can provide solutions to long-standing storage problems in Africa and elsewhere. While grain storage structures help protect against crop losses from insects, rodents, molds, theft, and fire, traditional designs are not always effective, and building them is difficult for poor communities where the hardwood supply is limited due to deforestation.

FIGURE 4.3. 5 Sealed stores—mud silo (A) and metal silo (B)

A. **B.**



Metal silos clearly do offer continuing opportunities for the reduction of Postharvest Losses in Sub-Saharan Africa .The main technical constraints for farmers using metal silos are the need to have their grain dry before storage and the need to undertake phosphine fumigation against pest infestation.

Bags and other storage structures (Figure 5.3.5) made of plastic have the advantage that they can be made airtight (hermetic). Under such conditions, bio-deterioration can be slowed. One such method currently under extensive promotion is the use of “triple bagging” for cowpea storage, although it could be adapted for grains. The triple-bagging technique was developed as an effective hermetic storage method in Cameroon using two inner bags made of 80 micron polyethylene and one outer, more durable bag to help protect against damage. Well-dried cowpea fills the first bag, which is tied shut securely using string. The first bag is placed within a second bag, and this is closed securely. A third bag is used to enclose the first two and to protect against damage. Clear plastic bags are recommended so that the cowpea can be inspected easily for any signs of insect attack. It is also recommended that the bags should remain sealed for at least two months after they are filled, and after they are opened, they should be resealed quickly to prevent entry of pests. The bags must be kept safe from rodents that might make holes in them and so break the seal.

FIGURE 5.3.5. IRRI super bag (the gas- and moisture proof liner)

Plastic drums (fig.6.3.5) of all sorts, including water tanks, can be sealed and used as effective hermetic grain store

Figure 6.3.5 Plastic granary

Plastic drums (fig.6.3.5) of all sorts, including water tanks, can be sealed and used as effective hermetic grain store

Figure 6.3.5 Plastic granary

FIGURE 7.3.5 The traditional mopane wood model

4.0 Conclusion

The storage structures used depend on the construction material available, amount of tuber produced, prevailing climatic condition of the area, purpose of yam tuber storage, socio-cultural aspects of storage and there sources of the farmer, in particular the availability of labour and capital. In the humid forest zone yam is stored in a yam barn which is the principal traditional yam storage structure in the major producing areas. Stores offer shelter to the grain, and in addition, hermetic stores by themselves also prevent pest damage. Grains can be stored in sacks of various types on both a small and large scale. For medium- or long-term storage, hermetic sacks may be used when benefits outweigh costs. In other situations, traditional mud stores (as well as more modern plastic or metal silos) may significantly reduce the Post Harvest Losses of smallholders. Such stores may be hermetic or at least sufficiently sealed to prevent pest access to grain.

5.0 Summary

Grain storage structures help protect against crop losses from insects, rodents, moulds, theft, and fire, traditional designs are not always effective, and building them is difficult for poor communities where the hardwood supply is limited due to deforestation.

6.0 Tutor Marked Assignment (TMA)

- Describe the yam barn
- Describe the different types of structures used in storing cereals crops

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