THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF AGRICULTURE

DEPARTMENT OF TRAINING, EXTENSION SERVICES AND RESEARCH

HARVESTING AND POST-HARVESTING TECHNIQUES

TRAINING COMPENDIUM FOR MODULE

CODE NAME: APT 04206

NTA LEVEL 4

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FOREWORD

Agricultural production in Tanzania is dominated by cereals and legumes which contribute more than 60% of the national food basket, and whose production has been increasing yearly due to various interventions. However, the grain subsector is experiencing high post-harvest losses of up to 40%. Such losses in postharvest operations are caused by lack of knowledge, inadequate access to technology and/or inadequate storage facilities. Thus, acquisition of knowledge on postharvest management will provide a quick reference to future extension agents who will be working with farmers in the field in Tanzania.

Presently, delivery of the knowledge on harvesting and postharvest techniques is not harmonized among training institutes under the Ministry of Agriculture and other private Agricultural Training Institutes. This leads to unequal delivery of postharvest handling knowledge among tutors. Postharvest handling technologies are highly demanded by farmers from their extension agents who are placed in all parts of the country. Therefore, promoting postharvest management, addressing all components of the postharvest system, introducing new technologies and being able to systematically guide extension agents (students) are paramount, as these extension agents will later guide farmers to ensure reduction of the losses after harvesting. It is our anticipation that this compendium will help bringing awareness of postharvest handling systems to safeguard food security in the country. The Ministry of Agriculture has developed this compendium to be used in formal training in both public and private Agricultural training Institutes in Tanzania.

This compendium contains five chapters; whereby the first chapter is introducing the general background information on pre-harvest and harvest techniques; and the second chapter gives details on harvesting principles. The third chapter deals with postharvest techniques of cereals, grain and oil seed crops by analysing the post-harvest system and related processes, activities, losses and recommended interventions. The fourth chapter provides an understanding of crop storage and methods of storage The last chapter provides an understanding of mycotoxin contamination to crops. The compendium will serve as a universal tool for training mid-career agriculture production technician students (Certificate in Agriculture Production at the NTA Level 4) in all agricultural institutes in Tanzania. The compendium will further provide illustrative and handy ideas leading to competent graduates in postharvest management. The preparation of this compendium is based on

Competency Based Education and Training (CBET) system whereby 60% of the course will be covered by practical and 40% theoretical understanding of the post-harvest management system. The compendium will be subject to periodic review based on emerging challenges and technologies.

The Ministry of Agriculture acknowledges the commitment of the HELVETAS Swiss Intercooperation for facilitating the development of the compendium on postharvest issues for cereals, legumes, roots and tubers and oil crops. It also thanks the Swiss Agency for Development and Cooperation for the financial support.

We thank the joint effort of technical experts from the Ministry of Agriculture (MoA) Headquarter and MATIs, Sokoine University of Agriculture (SUA), Mbeya University of Science and Technology (MUST), Mwenge Catholic University and Tanzania Research and Career Development Institute (TRACDI) for pioneering the development of this compendium.

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ACKNOWLEDGEMENT

The production of this compendium has been achieved by the Ministry of Agriculture, Department of Training Extension Services and Research (DTER).

We thank the joint effort of technical experts from the Ministry of Agriculture (MoA) Headquarter and MATIs, Private Agricultural Institute (PATI's), Sokoine University of Agriculture (SUA), Mwenge Catholic University, University of Dar es Salaam (UDSM), Mbeya University of science and Technology and Tanzania Agricultural Research Institute (TARI) for pioneering the development of this compendium.

We further acknowledge Mr. Osman Mushtag from University of Dar es Salaam, Dr. Zaharan Mgina from University of Science and Technology and Prof. Laswai Henry from Mwenge Catholic University for reviewing this document.

The Ministry of Agriculture acknowledges the commitment of the HELVETAS Swiss Intercooperation for facilitating the development of this compendium. It also thanks the Swiss Agency for Development and Cooperation for the financial support.

Further acknowledgement to the TANIPAC project for supported inclusion of issues of chapter five of the compendium on the issues of mycotoxin especially aflatoxin.

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LIST OF ABBREVIATIONS

APT	**=**	Agricultural Production Technicians
ASDP II	=	Agricultural Development Programme phase two
CBET	=	Competency Based Education and Training
CBLA	**=**	Competence Based Learning Activity
DAP	=	Day After Planting
EU	=	European Union
FAO	=	Food and Agriculture Organizations
GAP	=	Good Agricultural Practices
GDP	=	Gross Domestic Product
HDPE	=	High Density Poly-Ethylene
IARC	=	International Agency for Research on Cancer
MoA	=	Ministry of Agriculture
MATI	=	Ministry of Agriculture Training Institute
MBr	=	Methyl Bromide
MC	=	Moisture Content
PHM	=	Post-Harvest Management
PHL	=	Post-Harvest Losses
SELO	=	Sub-Enabling Learning Outcome
SPS	=	Sanitary and Phyto-Sanitary
SUA	=	Sokoine University of Agriculture
TBS	=	Tanzania Bureau of Standards
TRACDI	=	Tanzania Research and Career Development Institute
TV	=	Television
URT	=	United Republic of Tanzania
e.g.	=	Example
cm	=	Centimetre
g	=	Gram
kg	=	Kilogram
m	=	Meter
°C	=	Centigrade
***µ*g**	=	Microgram
%	=	Percent

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CHAPTER ONE

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iii.	Explaining types of post harvesting losses
iv.	Explaining the impact of post-harvest losses on food and nutrition security

Table 1.0: CBLA Matrix/Framework for Basic Information Related to Harvesting and Post Harvesting of Agricultural Produce

SN	CBLA	Time In Min.	Participatory /Activating Methods	Facilitation Materials/ Resources	Guidance Tools	Integrative Assessment Methods
a)	Understanding the situation and context of harvesting and post harvesting losses in Tanzania i) Defining terms related to harvesting and post-harvesting techniques (harvesting, post-harvesting, harvesting techniques, crop maturity, postharvest losses, postharvest waste and postharvest management ii) Explaining harvesting and post-harvesting losses in Tanzania	**60**	- Discussion - Brainstorming - Case study	- Multimedia (projector) - White board - Flip chart - Marker pens - Video - Crop materials with fungal growth	- Portfolio - SSAF	- Assignments - Written test
b)	Understanding postharvest losses i) Explaining primary and secondary causes of post-harvest losses ii) Describing post harvesting handling operations iii) Explaining different types of post-harvest losses (quantitative, qualitative and economic)	**60**	- Discussion - Brainstorming - Case study	- Multimedia (projector) - White board - Flip chart - Marker pens - Video - Crop materials with fungal growth	- Portfolio - SSAF	- Assignments - Written test
c)	Understanding the impact of postharvest losses on food and nutrition security i) Defining food security and food insecurity ii) Explaining causes of postharvest food losses	**60**	- Discussion - Brainstorming - Case study	- Multimedia (projector) - White board - Flip chart - Marker pens - Video - Crop materials with fungal growth	- Portfolio - SSAF	- Assignments - Written test -

TRAINING NOTES

1.1 Basic Information on Harvesting and Post-Harvesting of Agricultural Produce

1.1.1 Background Information

Agriculture is feeding the country. It is an important sector to the Tanzanian economy, accounting for about 65.5 % of employment; providing livelihood to more than 70 % of the population, and accounting for 29.1 % of GDP; 30 % of exports and 65 % of inputs to the industrial sector. However, meeting the food demand is an emerging big challenge to mankind due to rapidly increasing global population. The population is expected to grow to 9.1 billion people by the year 2050; where about 70 % extra food production will be required. Most of this population rise is expected to be attributed to developing countries, several of which are already facing issues of hunger and food insecurity. In the last few decades, most of the countries have focused on improving their agricultural production, land use, and population control as their policies to cope with this increasing food demand. Therefore, more attention is required on addressing the harvest and post-harvest losses (PHL).

It is estimated that one-third of the food produced is lost globally during harvest and post-harvest operations every year resulting into food loss. Results from the Food and Agriculture Organizations (FAO) from different research studies, reveal that farmers in Tanzania lose up to 40 percent of the harvest depending on the crop and location. This has a negative impact on their income, livelihood and food security. The Government in collaboration with other stakeholders has been implementing various interventions to address PHL through the Agricultural Sector Development Programme phase two (ASDP-II).

Over the past four years, production of cereals has been increasing from 8.9 to 9.5 million tons in 2017/18. Furthermore, Tanzania has great potential in the oil seeds sector, which can be scaled-up as one of its key sectors for industrial development. It is revealed that, the production of oilseeds in Tanzania mainly focuses on ground nuts (40%), sunflower (35%), sesame (15%), cotton (8%), and palm oil (1%). Despite all these facts and efforts, PHL for these crops are still high that calls for increasing adoption of improved harvesting and post-harvesting technologies by the farming community.

In the developing countries, crop harvesting is performed mainly manually using tools such as sickles, knives, hoes/forked hoe and cutters whereas in the developed countries almost the entire crop is harvested using combine harvesters. Therefore, harvesting timing and method (mechanical vs. manual) are two critical factors dictating the losses during the harvesting operations.

1.1.2 Definition of terms related to harvesting and post harvesting techniques

v. **Harvesting:** Is the removal and collection of the economic plant parts from their mother plants or entire plants (i.e. grains, seeds, leaves, roots or entire plant) after the maturity from the field.

vi. **Post-harvesting:** Is the stage of crop production immediately following harvest.

vii. **Harvesting techniques:** Are ways/methods of carrying out the process of gathering a matured crop from the fields.

viii. **Crop maturity:** Is that moment at which a crop has reached a sufficient stage of development and is ready for harvesting.

ix. **Postharvest losses:** PHL refers to a decrease, at all stages of the food chain prior to the consumer level, of food that was originally intended for human consumption, regardless of the cause. It is a measurable decrease in quantitative and qualitative terms in a given produce after harvest

x. **Food quality loss or waste:** Refers to the decrease of a quality attribute of food (nutrition, aspect, etc.), linked to the degradation of the product, at all stages of the food chain from harvest to consumption.

xi. **Postharvest waste:** Is a typical, but not exclusive type of food loss, it takes place at the retail and consumption stages in the food value chain; or at consumer level with food appropriate for human consumption being discarded or left to spoil, regardless of the cause.

xii. **Postharvest management**: Are methods and techniques applied to increase the shelf life of the harvested produce

1.1.3 Postharvest losses

Postharvest losses include the food loss across the food supply chain from the stage of harvesting to the point of consumption. The losses can broadly be categorized as weight loss due to spoilage, quality loss, nutritional loss, seed viability loss, and commercial loss. PHL accounts for direct physical losses and quality losses that reduce the economic value of the crop or may make it unsuitable for human consumption. Therefore, PHL can be measured both quantitatively and qualitatively, but also can be measured in terms economic loss of a produce across the supply chain (post-harvest system), from the time of harvest till its consumption.

1.1.3.1. Types of Postharvest Losses

Post-harvest losses are classified into 3 categories as described below;

i. Quantitative Loss

This is a physical reduction in the marketable volume and can be easily measured. Quantitative loss indicates the reduction in physical weight and can be readily quantified and valued. This is for example a portion of grain damage by pests or lost during harvesting, packaging, transportation and storage. Globally, quantitative grain losses are estimated to be 10–20 % of the total volumes.

ii. Qualitative loss

Qualitative loss refers to deterioration of nutrients/caloric composition, edibility, and consumer acceptability of the products. Qualitative loss data is hardly ever reported. But it's a loss that must concern everyone. For example the levels of qualitative losses due to aflatoxin contamination, although not reported, have direct long-term effects on health. Chronic dietary exposure to low doses of aflatoxins is a known risk factor for liver cancer and other health-related issues.

iii. Economic losses

Economic loss is the reduction in monetary value of the product due to a reduction in quality and/or quantity of food.

1.1.3.2 Causes of Post-Harvest Losses

A. Primary causes

A.1 Pre-harvest factors

Pre-harvest factors are production practices that affect post-harvest returns in quality and quantity. Pre-harvest conditions and actions in the field can indirectly lead to losses at later stages in the chain. Differences in production and agronomic practices can affect the quality at harvest, suitability for transport and shipping, storage stability and shelf-life after harvest. Furthermore, there are damages in the field before harvesting due to biological and biotic factors such as weeds, insect pests and diseases.

Overall, pre-harvest factors driving post-harvest food losses (qualitative and quantitative) can be divided into four groups: (i) Choice of crop varieties for the location and for the target market; (ii) Agronomic practices (including fertilization/nutrient management, water management, pest/disease management, pruning, staking, bagging, etc.); (iii) Biological factors and (iv) environmental factors. These factors can

lead to failure on attaining desirable quality attributes which leads to a high percentage of rejects/culls. Examples of pre-harvest factors that could potentially influence postharvest losses include the following:

i. **Water supply:** Growing plants need continuous water supply for both photosynthesis and transpiration. E.g. dry conditions followed by high moisture give rise to growth cracks or secondary growth in potatoes that affect its marketability.
ii. **Fertilizer application:** Inadequate application of nitrogen fertilizer can result in plant stunting and eventually low yield and poor quality of produce such as shrivelled grains. Inadequate potassium in roots and tubers results in slender roots that can be rejected at the market.
iii. **Weed infestation:** Weeds are commonly alternate hosts for crop diseases and insect pests; they also compete with crops for nutrients and soil moisture.
iv. **Application of agricultural chemical pesticides:** Pesticides (insecticides and herbicides) can damage produce by producing spray burns if used incorrectly, and they can leave poisonous residues on produce after harvest.

Harvesting is considered as the first step in the grain supply chain and is a critical operation in deciding the overall crop quality. Harvesting is also the crucial stage where crop commodities are more prone to losses. The magnitude of crop commodity losses and subsequent postharvest losses is dependent on a number of factors.

i. **Harvest methods:** Losses in most crops begin in the field (at farm level), and there is high chance they are induced by methods employed during harvest. Crop losses during harvest must put into consideration when deciding on which harvest method to be employed . In the developing countries, crop harvesting is performed mainly manually using tools such as sickle, knife, scythe, cutters whereas in developed countries the entire crop is harvested using combine harvesters.
ii. **Crop maturity:** The time of harvesting is determined by the degree of maturity. In cereals and pulses, a distinction should be made between maturity of stalks (straw), ears or seedpods and seeds. Inadequate knowledge on crop maturity results in large amount of losses through moulds and the decay of some of the seeds during the harvesting operations. Late harvesting results in shattering of grains, germination when it rains, and breaking during processing and changing of seed colour. All these factors affect the grain quality and subsequent marketing.
iii. **Harvest time:** Harvesting timing is a critical factor dictating the losses during the harvesting operations. Lots of losses occur before or during the harvesting operations, if they are not

performed at adequate crop maturity and moisture content. Too early harvesting of crop at high moisture content increases the drying cost, making it susceptible to mould growth and insect infestation, and resulting in a high amount of broken grains and low milling yields. However, leaving the matured crop un-harvested results in high shattering losses, exposure to birds and rodents attack, and losses due to natural calamities (rain, hailstorms, etc).

A2. Post-harvest factors

Significant quantitative (physical amount) and qualitative (degradation in quality) crop losses occur after (post-) harvest. Some operations after harvest such as threshing and cleaning, and winnowing, drying, transport and storage are often associated with losses of crops.

a) Post-harvest handling operations

i. **Threshing:** Grain spillage, incomplete separation of the grain from chaff, grain breakage due to excessive striking, are some of the major reasons for losses during the threshing process. Delay in threshing after harvesting of crop results in significant quantity and quality loss, as the crop is exposed to atmosphere, and is susceptible to rodents, birds, and insect attack.

ii. **Cleaning:** is a process performed after the threshing to eliminate impurities (foreign materials, such as straw, stones, sand, chaff, and weed seed) mixed with the grains. This process is normally accompanied by sorting of the grain according to quality. Grain cleaning improves the drying and storability of grain, reduces dockage at the time of milling and improves milling output and quality.

iii. **Winnowing:** is the simplest cleaning method consisting of tossing the grain into the air and letting the wind carry off the lightest impurities like unfilled grains, chaff, lighter weed seeds and straws. It is a very common method used for cleaning in the developing countries. Although widespread in farming circles, this cleaning method does not eliminate the heavier impurities like gravels, stones, foreign grains, heavier weed seeds, off types and dirty. However, large quantities of grains are lost as spillage during this operation, and grain losses during winnowing can be as high as 4% of the total production.

iv. **Drying:** Grains are usually harvested at high moisture content to minimize the shattering losses in the field. However, for long-term storage of the crops, the recommended moisture content is 14% maximum. Inadequate drying can result in mould growth and significantly high losses during storage and milling. Therefore, proper drying has four main advantage:

- To maintain the crop quality
- To minimize potential infestation during storage
- To reduce transportation cost
- To maintain considerable weight for market purposes

The ideal cereal moisture content at harvest is between 18% and 20% which is above the ideal moisture content for stored cereals. Therefore, it is important to bring the moisture down to 14 % if you plan to sell soon, since that is the ideal moisture content for a high selling price.

v. **Transportation:** Refers to the movement of grains from one step to another, such as field to processing facilities, field to storage facilities, and processing facilities to market. Lack of adequate transportation infrastructure results in damage of food products through bruising and losses due to spillage.

vi. **Storage:** Storage means the phase of the post-harvest operation during which the grains are kept in appropriate conditions for future use without any entry or multiplication of pests. Main objectives of storage are;

- To ensure food availability throughout the year
- To enable selling of grains during off season where prices are higher
- To ensure availability of seeds for the crop cycles to come
- To guarantee regular and continuous supplies of raw materials for processing industries and marketing
- To prevent grain damage and maintain grain quality.

In order to attain these objectives and avoid grain losses, it is necessary to adopt proper storage measures throughout the storage time.

The grain and oil seeds storability are affected by two main factors which are:

i. Biotic factors, which includes microorganisms (fungi, bacteria and yeast/moulds) insects and mites, rodents, birds and metabolic activities

ii. Abiotic factors, which includes grain temperature, moisture content, initial grain condition. Moisture content and temperature are the most crucial factors affecting the storage life of grain and oilseeds.

b) Chemical treatment

i. **Pesticides:** Synthetic insecticides are used in several countries and play an important role in controlling the pests and reducing losses during storage of grains. However, irrespective of their

effectiveness, synthetic insecticides, such as residuals from synthetic fumigants could cause considerable qualitative loss (e.g. loss of seed viability). Furthermore, the delayed treatment, adulterated chemicals, and/or incorrect dosage can reduce the efficacy of the treatment and result in high storage losses.

c) Post-harvest mechanical, physiological and biochemical deterioration

i. **Mechanical damage:** Injuries caused by rough handling of a produce. It includes bruising, abrasion, puncture and broken which result in loss of both quality and quantity due to subsequent decay.

ii. **Physiological deterioration:** Caused by physiological processes e.g. respiration resulting from breakdown of food reserves and the aging result in qualitative losses (e.g. quality loss of colour, composition, texture, flavour and nutrient content).

iii. **Biochemical reactions:** Damage caused by enzymatic reactions during storage of a produce giving rise to change of flavour, discoloration, softening and decay.

iv. **Mechanical damage:** (e.g. Roots and tubers) such as bruising, abrasion, or puncture and broken. That influence negatively the appearance of the food commodity.

B. Secondary causes

i. Inadequate knowledge, skills and lack of awareness on post-harvest management

ii. Poor/lack of infrastructure like field roads, irrigation infrastructures, processing and storage facilities

iii. Poor/inadequate post-harvest handling equipment such as threshers, driers and moisture meters

iv. Lack/inadequate/expensive packaging materials/containers for the transport of the produce

v. Lack/inadequate/expensive materials for handling of produce

vi. Lack of markets; poor planning and lack of market information

vii. Quality grades and standards, which result in retention or rejection of crops for human use by being too lax or unduly strict

viii. Inadequate access to post-harvest technologies by farmers

ix. Bumper harvest; this can overload the post-harvest handling system or exceed the consumption need and cause excessive wastage

x. Poor planning in regard to crop selection and timing to meet the expected market requirements

xi. Inadequate planning of harvesting and post-harvesting operations (good timing, arranging for labour, equipment, transport and effective supervision).

Different food commodities are affected differently as summarized below (Table 1.1)

Table 1.1: Summary of Causes of Post-harvest Losses for Selected Crops

Group	Crop	Major causes of postharvest losses
Cereals	Rice, maize, sorghum, millets	• Late harvesting leads to over maturity that results in breakages or shuttering • Improper drying results to breakages • Harvesting by traditional hand cutting that causes mechanical damage and may leave part of the harvest underground • Poor irrigation and field road infrastructure • Field stacking and bundling • Pests and diseases
Pulse, Oil seed	-Beans -Soya beans -Groundnuts -Sunflower	• Late harvesting leading to over maturity that results in grain splitting • Insect pest attack
Roots and Tubers	-Yams -Cassava -Sweet potato -Round potato	• Late harvesting leads to over maturity that results in fibre development that lowers quality • Poor packaging and transportation that results in bruises • Insect pests that damage quantity and quality • Sunlight results to black strips in cassava, and green coloration in potato

1.1.4 Impact of Post-harvest Losses

The effects of post-harvest losses pose potential negative impacts on food and nutrition security at local regional and global level. It can also negatively affect the income of small holder farmers.

i. Food Security and Food insecurity

Food security refers to the state of having reliable access to a sufficient quantity and quality of affordable, nutritious food. On contrast, food insecurity refers to the situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth, development and an active healthy life. Post-harvest losses reduce food availability and therefore cause hunger. PHL could also mean nutrient losses, which negatively impact nutrition status.

Post-harvest quality loss has an impact on nutrition if mycotoxin or other substances, which can interfere with the health status of the body, contaminate the food. Therefore, efforts to reduce PHL along all segments of the supply chain coupled with appropriate post-harvest management have a potential to improve food and nutrition security by capturing otherwise lost nutrients and create profitable, accessible and affordable diversified diets.

ii. Economic, Social and Environmental Impacts

Economic impact: Post-harvest losses not only reduce food availability to the community but also affect smallholders' income. PHL reduce the monetary value of the product as they reduce quality and/or quantity of food. Businesses and consumers spend a larger portion of their budget on foods that will not be sold or consumed.

Social impact: Socially, PHL have a potential impact on low-income consumers with fewer resources for purchase of food.

Environmental impact: PHL results in substantial amount of garbage and waste, contamination of individuals in rural and urban areas.

The main causes of postharvest losses are shown in Fig. 1.1.

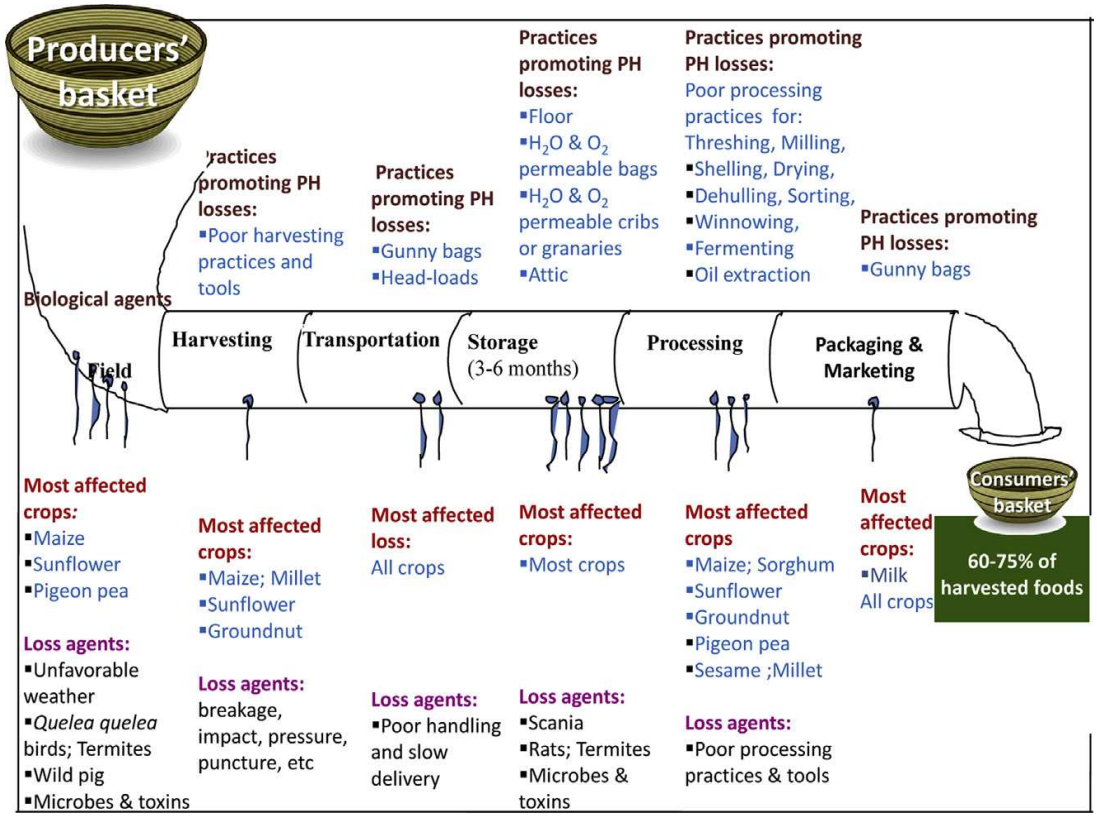

Figure 1.1: Post-harvest food pipeline

CHAPTER TWO

2.0 APPLYING HARVESTING TECHNIQUES TO A GIVEN CROP

2.1 Sub-Enabling Learning Outcome (SELO): Apply Harvesting Techniques to a Crop

2.2 Competence Based Learning Activities (CBLA)

i.	Assessing signs of crop maturity for harvesting
ii.	Estimating crop yield using different methods
iii.	Selecting recommended techniques for proper harvesting
iv.	Harvesting crops focusing on reducing losses

Table 2.0: CBLA: Matrix/Framework

Sn	CBLA	Time in minutes	Participatory/ Activating Methods	Facilitation Materials/ Resources	Guidance Tools	Integrative Assessment Methods
a)	Assessing signs of crop maturity for harvesting i. Understanding the basic concepts related to harvesting (harvesting, crop maturity, maturity indices etc) ii. Differentiate crop maturity stages iii. Identifying the signs of crop maturity (practical skill)	30	Field visit Demonstration Discussion	Multimedia (Video, projector, TV	Logbook for reflection	- Skill Test - Observation of performance
b)	Estimating crop yield using different methods i. Understanding the basic concepts related to crop yields (yield estimation) ii. Computing yield estimation (practical skill)	45	Lecture Field visit	Chalk board/Flip sheets/Calculators	SSA/Log-book for reflection	Project assignment Competence test
c)	Selecting recommended techniques for proper harvesting i. Identifying appropriate materials, tools and equipment for specific crop harvesting (practical skill) ii. Preparing for harvesting and post harvesting activities iii. Determining proper crop harvesting time	35	Demonstration Jig saw method Discussion Buzzy group discussion/ Lecture	Different harvesting materials/ Projector/TV	Logbook for reflection/ SSA	Written knowledge test Competence test
d)	Harvesting crops focusing on reducing losses i. Identifying harvesting method for specific crop to minimize looses ii. Identifying harvesting practices for specific crop to minimize looses iii. Performing the procedures for harvesting specific crop (practical skill)	40	Demonstration Jig saw method Discussion	Projector/TV	Logbook for reflection/SSA	Skill test Project assignment

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2.3 Signs of Crop Maturity for Harvesting

2.3.1 Basic Concept

i. Harvesting

Harvesting is the process of gathering of mature crops from the field. It is important to harvest on time to avoid losses that can be caused by diseases, animals, insect pests, fire, thieves, and weather.

ii. Crop maturity

The term crop maturity refers to a stage where a crop has completed physiological growth and development. Most postharvest technologists consider crop maturity to be "that stage at which a commodity has reached a sufficient stage of development that after harvesting and postharvest handling (including ripening, where required), its quality will be at least the minimum acceptable to the ultimate consumer".

iii. Maturity Indices

These are the signs or indication of the readiness of the crop for harvest is termed as maturity indices. It is the basis for determining harvest date/time.

iv. Signs of Crop maturity

The signs of crop maturity are listed in the Table 2.1 below

Table 2.1 Maturity indices for various crops

Crop Group	Crop Name	Maturity time after planting	Maturity indices sign
Cereals	Maize	3 – 8 months	- The crop is mature when the plant has become straw coloured (light brown), the grains are hard, and the cobs drop bend down (drooping). - Cob maturity can also be tested by checking for the black layer that forms at the base of the grains (they connect to the cob). The layer can be seen by removing grains from the cob and scraping the base with your fingernail. - The moisture content is 23 to 28% depending on climatic condition This can be tested by using moisture meter.

	Paddy	2.5 – 5 months	- The crop should be harvested when nine out of ten grains on the panicle are straw coloured. - They have a moisture content of around 20-25%, which can be tested by using moisture meter. - Mature grains are firm but not brittle when squeezed between the teeth. - 70% of the kernels change colour to yellow / brown.
	Wheat	3 – 4 months	- The panicles change from green to greyish brown, - Yellowing and drying of leaves, - Moisture content of the kernels approaches 18 to 20%.
	Sorghum and millet	3 - 6 months	- Yellowish to brown leaves, - Moisture content between 16% and 20 %, - Stem and leaves start to dry up and change into brown, - Colour of the head changes from green to grain colour (white or red), - Development of a black layer at their base when mature, - Grains tend to reach physiological maturity while the stalks and most of the leaves are still green.
Legumes	Common beans, Soya beans, Chickpeas, Pigeon pea	2.5 - 4 months	- Colour of the pod changes from green to yellow and to brown, - Yellowing of the leaves, - Shedding of the lower old leaves, - Grain becomes hard, - Darkening/whitish/brown of the pod depending on cultivar.
	Bambara groundnuts	3 - 5 months	- Yellowing of the leaves, - Colour of the pod changes from green to red/ whitish, - Detachment of the pod from the mother plant.
Oil Crops	Groundnut	2.5 – 4 months	- Colour of the pod changes from white to whitish, - Hardening of outer shell, - The inner side of the pod becomes black, - Seed changes from white to red and brown depending on the variety.

			- Yellowing of the leaves, - Easy detachment of the pod.
	Sesame	3 - 5 months	- Yellowing of the leaves, - The pods change from green to brown, - Seed becomes black/pale green, - Slightly bending of the mother plants.
	Sunflower	4 - 5 months	- Head changes from green / yellow to brown, - Grains change from whitish to white/black, - Change of colour of disc floret from yellow to brown, - Detachment of disc floret, - Shedding of the old leaves, - Bending of the head.
Root Crops	Round / Irish potatoes	4 - 5 months	- Dropping of the leaves, - Drying of the leaves, - Change of fruits colour from green to brown/white, - Shrinkage of stem, - Senescence of the shoot.
	Cassava	6 - 12 months	- Cracking of the soil (except clay soil), - Drying of lower leaves, - Yellowing of the old leaves, - Shedding of leaves.
	Sweet potatoes	4 - 6 months	- Cracking of the soil, - Yellowing of the leaves, - Vines stops growing.

2.3.2 Estimating crop yield using different methods

Basic Concepts

i. Yield estimation

Crop yield estimation is the process of projecting as accurately as possible the quantity of crop that will be harvested. Yield estimation:

- Helps in planning for food security of the population of a district or even of the whole country,
- Helps for timely interventions in case low yields are predicted,
- Helps farmers to prepare the packaging materials and storage space,
- Assist in analysis of harvesting cost,

- Helps in planning for the next season,
- Helps in delivery estimates.

ii. Yield Estimation Methods

There are many methods available for farmers and others to estimate yield of various crops. The method presented in this compendium is one that can be undertaken relatively quickly and easily.

Steps for yield estimation are as follows:

- Selection of an area that is representative of the farm.
- Use a measuring tape to measure one metre square and count the number of heads, pods or cobs.
- The sample taking is replicated 5 times in different places (i.e. do it 5 times to get an average of the crop).
- Count the number of grains in at least 20 heads, pods or cobs.
- Determine the grain weight for the crop concerned.
- Use the standard method of estimating yield of different crop grains as given in a table below (i.e. Follow through the calculation outlined below).

NB: Accuracy of the method depends upon adequate number of counts being taken so as to get a representative average of the farm.

Table 2.2 Methodology for estimating grain yield

S/N	Steps	Examples
1	Number of heads/pods per square meter	a = 150
2	Av**erage number of grains per head/pod**	**b = 25**
3	**Number** of grains per square metre = a x b	c = 150x 25 =3750
4	Yield per square meter = c/100 x 3.2 g	d = 3750/100 x 3.2 = 120 g
5	Yield in t/ha = d/100	e = 120/100 = 1.2t /ha

The same method can be used for any other type of grain crop as long as you choose the correct seed weight from **Table 1.** The basis behind this method for estimating yields is the counting of heads or pods per square meter.

2.3.3 Selecting recommended techniques for proper harvesting

Delay of harvesting crops in the field can lead to spread of pests and diseases from the field to store. Crops such as rice, millet and finger millet have a tendency to shatter, resulting in excessive loss in the field. Thus, it is best to harvest in time to prevent unnecessary losses. Harvesting will also depend on the

intended use of the crop(s). For example, millet intended for animal feed is harvested before giving panicles, while corn for roasting should be harvested before complete drying with moisture content ranging from 60 to 80%. Harvesting varies depending on the type of the produce, e.g. harvesting of cassava is different from that of maize and intended use of the produce. Important factors to consider before harvesting:

- Preparation for harvesting and postharvest activities
- Harvesting materials, tools and equipment
- Determination of proper harvesting time
- Market conditions (specifically for roots and tubers)

i. Identifying harvesting materials, tools and equipment

The harvesting tools/equipment and materials differ according to the type of crop and intended use. It is important to take into account the use of appropriate equipment and the most effective way of harvesting according to their type. The most common ones include:-

- Tools/equipment and machines; hand hoe, sickle, knife, machete, reaper, rake, combine harvester
- Materials used during harvesting are; bags, bucket, basket, tarpaulin and crates

ii. Points to consider during preparation for harvesting and postharvest activities

- Decide and allocate places where activities will take place, e.g. drying and threshing areas
- Equipment needed for harvest and postharvest activities are available and in good condition
- Sufficient storage space for the produce is available
- Storage structure and sacks have been thoroughly cleaned and repaired before the new harvest arrives in order to avoid contamination of new crops with last season's crop
- Residues of the old harvest (last season's crop) are removed from all cracks and crevices and either burnt or fed to animals (alternatively, they can be stored in a separate place and consumed)
- Checking the field to see if the crop is mature
- Making sure the field is free from weed so as to avoid produce losses and rodent infestations
- The moisture content of the grain such as cereals, legumes and oil crops should range from 20 to 28%. Grains should be firm but not brittle when squeezed between the teeth
- For the root crops it depends on the size desired by the market.

NOTE: Observe good hygiene to prevent postharvest losses along the supply chain.

iii. Determination of Proper Harvesting Time

Proper harvesting time is crucial as it reduces crop loss, ensures good produce quality and high market value. It is recommended that crops are harvested as soon as they reach their physiological maturity. Determination of proper harvesting time includes the timely harvesting, early and late harvesting. However, early and late harvesting are not recommended as they have several disadvantages;

A. Timely harvesting

Timely harvesting means detaching the produce from the mother plant as soon as it reaches its physiological maturity. However, harvesting of some crops depends on:

i. Market and processing condition: E.g. in root crops, certain markets need different sizes of the produce depending on consumer preference.
ii. Intended use: For example, millet intended for animal feed is harvested before giving panicles, while corn for roasting should be harvested before complete drying with moisture content ranging from 60 to 80%. Tender maize or legumes are consumed as vegetable.
iii. Market demand: E.g. harvesting of root crops depends on the size desired by the market.

Timely harvesting:

i. Avoids or reduces crop losses,
ii. Ensures good produce quality,
iii. Ensures high market value.

B. Early Harvesting

Refers to the harvesting of the crop before their physiological maturity. The disadvantages of early harvesting are:

i. Higher percentage of unfilled or immature grains,
ii. Shrinkage during drying,
iii. Weight loss in grains and oil crops/lower starch content,
iv. Cause reduced seed viability,
v. Shortened shelf life,

vi. Lower oil content in oil crops,
vii. Higher grain breakage during milling particularly in rice, and
viii. Mould infestation and subsequent aflatoxin contamination of grains and oil seeds.

C. Late harvesting

Refers to the harvesting of the crop beyond its physiological maturity. The disadvantages of late harvesting are:

i. Infestation of insect pests in grains and oil crops resulting into carrying over the pests into storage, leading to serious damage,
ii. Shattering and scattering in paddy rice, millet and sorghum and many types of beans,
iii. Increased breakage in rice during milling,
iv. Damage by birds and other wild animals,
v. Lodging,
vi. Sprouting in grains and oil crops,
vii. Woody and fibrous root crops,
viii. Starch is converted to simple sugars and hence, loss of quality (sweet potatoes and cassava),
ix. Theft,
x. Late release of the field for the planting of next crops, and
xi. Mould infestation and subsequent aflatoxin contamination of grains and oil seeds.

2.3.4 Harvesting Methods for Crops Focusing on Reducing Losses

There are different methods that are recommended for harvesting different crops. However, precautions should be taken before employing any of the methods to minimize losses which include preparation of harvesting materials, moisture content of the crop, drying places. Harvesting methods differ according to the part of the plant to be used. In crop production, there are two methods of harvesting, namely manual and machine harvesting.

a) Manual harvesting

The process of harvesting crops by using hand and/or simple tools to detach a produce from plants in fields is known as manual harvesting that include;

i. Hand picking e.g. maize, beans, peas

ii. Cutting of spikes or panicles/head (capitulum) e.g. paddy, wheat, sorghum, millet and sunflower
iii. Lifting e.g. cassava
iv. Digging e.g. sweet potato, cassava
v. Cutting crop below the ground (sesame and rice).

Advantages of manual harvesting

i. Allows harvesting of only mature/ripe produce
ii. Grade wise harvesting/ selective harvesting can be practiced
iii. Minimum damage to produce if harvesting is done properly
iv. Harvested produce is relatively clean.

Disadvantages of manual harvesting

i. It is costly in terms of labour and time
ii. It is tiresome exercise
iii. It is slow to the extent that some produce will pass maturity/ripe stage before the exercise is completed e.g. cassava

b) Machine harvesting

Is a process whereby a machine is used to detach produce from the mother plant e.g. combine harvester and strippers in grain.

Advantages of machine harvesting

i. The process is fast, hence reduces time
ii. Less wage labour
iii. It is possible to collect the produce direct in containers

Disadvantage of machine harvesting

i. Produce damage is high due to mechanical bruises/ abrasion
ii. There is no selective harvesting
iii. Requires skilled personnel
iv. It is more expensive
v. The produce bulk contains a lot of debris, hence it increases cleaning costs

2.3.5 Harvesting Practices For Crops

Harvesting practices differs between crops. It is important to take into account the use of appropriate equipment and the most effective way of harvesting according to the type of crop. Harvesting varies depending on the type and intended use of the produce, e.g. harvesting of cassava is different from maize. Make sure that the harvested crops are placed on clean mats, tarpaulins or directly into bags in order to avoid:

i. Contact with the soil which can lead to moisture uptake
ii. Staining from the soil
iii. Transfer of fungal spores that can lead to fungal growth and mycotoxin production
iv. In the case of bean pods, it is best to discard any that have come in contact with the soil as these are frequently damaged.

a. Maize harvesting

i. Pluck maize cobs from the plant
ii. Place them on a tarpaulin or direct into the bucket, basket or bag
iii. Transport the harvested cobs to the drying area
iv. Leave the cobs to dry either with or without ear.

However, it is recommended to dry maize cobs without ear because;

i. It allows the crop to dry fast
ii. Minimizes the risk of contamination from fungal growth and mycotoxin
iii. Enhances the advancement of threshing, winnowing and grading, i.e. to complete handling activities within a short time.

Note: Drying of husked cobs should be practiced only if there is a danger of cobs getting wet due to rainfall during drying.

b. Rice/Paddy harvesting

The harvested part of the crop plant is the panicle, where the following procedures should be observed;

i. Cut straw/plant at about 15 cm above the ground using sharp knife or sickle
ii. Heap the cut plants with their heads or panicles on a tarpaulin in a roundish form, with the heads pointing towards the centre

iii. Leave the cut plant for about 24 to 36 hours to allow drying for easy threshing.

Note: Paddy may also be harvested by using combine harvesters.

c. Sorghum, Wheat and Millets harvesting:

For sorghum, wheat and millets, the harvested part of the crop plant is the panicle. The following are the procedures of harvesting**;**

i. Cut the heads/panicles from a standing stalk by using sharp knives/sickles, Spread them on a tarpaulin to dry and

ii. Separate healthy heads/panicles from diseased ones.

Note: The crops may also be harvested by using small grain combine harvester.

d. Legumes harvesting (Common beans, Soybeans)

The harvested part of the crop plant is a pod. The following are the procedures of harvesting legumes;

i. Uproot the whole plant

ii. Place the uprooted plant on a tarpaulin and

iii. Leave them to dry for three days depending on weather

Note: However, in advanced farming, soybeans may be harvested by using combine harvesters.

e. Groundnuts harvesting

The harvested part of the crop plant is a pod. Groundnut harvesting depends on the type whether bunch/ erect type or spread type. Following are procedure of harvesting groundnuts;

i. Bunch type: Pull out the whole groundnut plants manually

ii. Spreading type: Use a blade harrow or ox plough, or do it manually by digging

iii. Collect the all self-detached pods and place them in a bucket or basket.

Note: Make sure the soil is sufficiently moist for easy harvesting to avoid losing pods in the soil.

f. Sunflower harvesting

The harvesting part of the sunflower crop is the capitulum. Harvesting is done manually. The following is the procedure of harvesting sunflower:

i. Chop the mature and bend downward heads with a sharp knife or by hand

ii. Spread the chopped heads on mats or elevated concrete floor on open wind space for drying.

Note: Avoid peeling as may undergo rancidity of oil seeds and germination of a fungus *Aspergilus flavus* that could cause aflatoxins.

g. Cassava harvesting

Harvesting of cassava roots is done by hand and easier when the soil is moist. Harvesting is also easier if planting is in ridges or in bed and sand in loose or sandy soil. The following are the procedures for harvesting cassava:

i. Cut back the main stem of the plant to a height of 30 – 50 cm using bush knives/machete to facilitate lifting

Note: During dry season, the upper part of the cassava plant should be removed several weeks prior to harvest. Removing the vegetative growth part will lengthen the shelf life of cassava by several weeks.

ii. Dig around the roots to free them prior to lifting the plant

iii. Slowly, pull the stem from the soil to draw the roots from the soil.

Note (1): While lifting, care should be taken not to break the roots or split the skin as the wounded tissue is the entry point for decay causing micro-organisms.

Note (2): During dry season, the upper part of the cassava plant should be removed several weeks prior to harvest. Removing the vegetative growth part lengthens the shelf life of cassava by several weeks.

iv. After pulling the plant from the ground, remove the roots (Cassava) from the plant by hand. Note that care should be taken during harvesting process to minimize damage to the roots as it may result into higher amount postharvest moisture loss and secondary decay.

h. Sweet Potatoes and cocoyam harvesting:

The harvesting of sweet potatoes and cocoyam is done by digging using a hoe. The economic part of the crop plant is the root/tuber. The following is the procedure of harvesting sweet potatoes and cocoyam**;**

i. Prune the vine of the sweet potatoes and cocoyam,

ii. Dig to the remove the produce from the soil,
iii. Collect the produce together,
iv. Spread the produce on a slab/floor/canvas for cleaning, preferably in the shade and
v. Tubers are removed off soils and some tails on both ends.

Note: During harvesting avoid damage and injury to the produce, because it will cause spoilage and quality loss.

CHAPTER THREE

3.0 APPLYING POST-HARVEST TECHNIQUES TO A GIVEN CROP

3.1 SELO: Apply post-harvest techniques to a given crop

3.2 CBLA

i.	Understanding post-harvest techniques and terminologies
ii.	Understanding the post-harvest techniques for different crops
iii.	Understanding post-harvest operations at crop slab or pack house or laboratory

Table 3.0: Designing Competency Based Learning Activities Matrix

Sn	CBLA	Time in minutes	Participatory/ Activating Methods	Facilitation Materials/ Resources	Guidance Tools	Integrative Assessment Methods
a)	Understanding post-harvest techniques and terminologies i. Defining postharvest handling, postharvest technology ii. Explaining the importance of postharvest techniques iii. Identifying equipment and material used for postharvest operations of crops (e.g. *Tarpaulin, mats machine driers, winnower, sieves, destoner, washers, sticks, mechanical sheller, thresher, sieves, beam balance, bags/sacks, plastic and wooden crates, cribs, silo, hermetic bags, underground pits, drums, tins etc)*	**120**	Discussion Lecturette Brainstorming Jig saw	- Multimedia (Video drives, projector, TV) - Computer	Logbook for reflection	- Written test - Assignment
b)	i. Understanding the postharvest techniques for different crops ii. Explaining the facilities to be used for post harvesting operations iii. Describing common post-harvest operations for crops iv. Describing postharvest procedures or steps for cereals, legumes, roots and tuber crops v. Describing the procedure for grain treatment vi. Adjusting crop yield for storage purposes	**90**	- Lecturette - Discussion - Jig saw - Demonstration - Site Visit	- Real materials - Multimedia (Video drives, projector, TV) - Computer - Site visit - Drier, Sheller, grater, miller, thresher, winnower, air blower, sieves, chemicals	- SSAF - Portfolio	- Observation of performance - Written test
c)	Understanding Post harvesting operations at crop slab or pack house or laboratory i. Carrying out postharvest operations at a slab or pack house (Practical) **ii.** Performing quality test for different crop produces in laboratory	**180**	- Demonstration - Site visit	- Drier, Sheller, grater, miller, thresher, winnower, air blower, sieves, chemicals	- SSAF - Portfolio	- Competent test

TRAINING NOTES

3.3 Basic Concepts Related To Post-Harvest Techniques and Terminologies

3.3.1 Post-harvest handling

Post-harvest handling involves the operations that produces undergo from harvest to the time immediately before meal preparation. The main concern is to keep produces in an acceptable state from harvest until it reaches the consumer. Moreover, postharvest handling aims at minimizing losses to the lowest possible cost. The existing postharvest environment requires appropriate technologies to maintain quality of produces. Poor handling of agricultural produces can result in quality deterioration and quantity losses.

3.3.2 Post-harvest technology

Postharvest technologies (PHT) are methods or art applied to agricultural produces after harvest for the purpose of preservation, conservation, quality control/enhancement, processing, packaging, storage, distribution, marketing, and utilization to meet the food and nutritional requirements of consumers in relation to their needs.

3.3.3 Importance of applying post-harvest technology

Overall, postharvest technology and/or activities is/are applied to achieve one or a combination of the following functions; preventing losses, extending shelf life, adding value and maintain the already present quality of an agro-produce. Objectives of applying PHT:

i) Improving nutritive value of a produce
ii) Opening new marketing opportunities
iii) Generating new job opportunities
iv) Protecting and ensuring produce safety
v) Reducing losses between harvest and consumption.

3.3.4 Postharvest techniques

Refers to methods of doing or practising different operations in a given produce soon after harvesting. Common postharvest operations are:

I. Cleaning:

A process of separating contaminants from raw materials. Typical nature of contaminants includes sand, dusts, stones and metals, plant stalks, leaves, twigs and pods, animal hairs, feathers, droppings, bones, insects and insect fragments, chemicals pesticides and fertilizers, microbial cells and product of cell metabolism e.g. pigments.

Importance of cleaning

i. To protect consumers against potential harmful materials,
ii. To protect the produce from trade description legislation and tarnishing of images,
iii. To protect from damaging machinery from stones and other hard contaminants and inadequate processing due to high number of bacteria and
iv. To reduce unnecessary bulkiness of the produce especially during transportation

Cleaning methods

There are two types of cleaning: 1) Dry cleaning and 2) Wet cleaning.

Dry cleaning includes brushing, screening, abrasion, aspiration, physical separation and magnetic separation (see Table 3.1).

Table 3.1: Dry cleaning methods

Cleaning Method	Explanation
Brushing	Produce pass close to brushes, then brush removes dusts and other particles by rinsing
Abrasion	Includes all techniques that physically abrade the building surface to remove soil, discoloration or coating. Such techniques involve the use of certain materials which impact or abrade the surface under pressure or abrasive tools and equipment
Aspiration	Basically air is used for separation; it employs different density between air for the contaminants to be removed, the lighter materials like leaves, twigs and dusts are carried away with air
Screening	Commonly screening is done by using screens and is based on particle size
Magnetic cleaning	In this process the contaminants are attracted to the magnet fused on the conveyers/ rollers or drums
Physical separation	This is based on the physical attributes between raw materials and the contaminants, e.g. weight, colour, shape, and size
Winnowing	Implies the cleaning with purposes of removing chaffs, loose husk, stones and leaves before it goes to the next step. However, there are two types of winnowing which are manual and machine winnowing.

- **Manual winnowing**

The traditional way of winnowing is making the dried grains fall from a height using shovels and a sieve. Crop grains are first placed on a bamboo tray or any other appropriate material. The quality grains which are heavy fall vertically while the weightless chaff and straw get blown away by the wind while the grain fall onto mats/canvas/slab. Thus, winnowing is effective only when there is a wind. Farmers often have to wait for hours for the wind to blow before they could start the process of winnowing.

Figure 3.1: Winnowing of grains using weaved bamboo strip round

- **Machine winnowing**

The process of winnowing using machine involves cleaning of grains by the action of riddles and sieves and an air blast, fanning machine or fanning mills.

Figure 3.2: Winnowing by using winnower machine

Advantages of dry-cleaning

i. It is cheaper than wet cleaning
ii. Cleaned surface is left dry
iii. Efficient if concentrated and easily disposable
iv. Plant cleaning is simple
v. Chemical and microbiological reactions are inhibited

Disadvantages of dry-cleaning

i. Adherent soil is incompletely removed
ii. It is dusty, hence personnel respiratory diseases are likely to occur
iii. Product damage is often higher than in wet cleaning process because of abrasion

Wet cleaning methods are effective in removing firm adherent soils and allowing the use of detergents and sanitizers. Wet cleaning methods includes: Soaking and spraying

Soaking: This method is often used as preliminary stage of cleaning root crops that are heavily contaminated to allow softening of contaminants. In soaking, water can be thermostatically controlled but temperature must be at a level that does not give rise to spoilage.

Spraying: This is the spraying of the produce with water, and is the most popular wet cleaning method, where it removes adherent soils and areas of microbial contamination and rots. However, the efficiency of spray cleaning depends on;

i. Amount of water pressure employed
ii. Volume of water used
iii. Water temperature
iv. Distance from the produce and sprayer nozzle
v. Time of exposure of the produce to the spray
vi. Extent of sprays

Advantages of wet cleaning

i. More effective in removing adherent soils
ii. Dustless
iii. Product damage can be reduced if equipment design is good and
iv. It is flexible, hot processes using detergents and sanitizers are possible

Disadvantages of wet cleaning

i. Requires expensive plants with sanitation problem
ii. Chemicals and microbial reactions can be accelerated
iii. There is a problem in disposing voluminous and dilute effluent and
iv. Produce surface is left wet, hence dewatering or drying is necessary

II. Threshing/shelling

Threshing/shelling is the process which separates the grains with its protective husk from the stalk of the plant. It is customary for the crop to be threshed soon after harvesting. This separation, done by hand or machine, is obtained by threshing, by friction or by shaking the products; the difficulty of the process depends on the varieties grown, and on the moisture content as well as the degree of maturity of the grain.

- **Manual threshing**

The sheaves of crop may be flailed against a mound of earth, a log of wood, a special threshing ladder or a wooden slat. The grains are separated from the head of plants and collected in a tub. Where animals are used, the sheaves are brought to the threshing floor and laid around a central stake, with the heads of plant pointing toward the stake; the cows are tied to the stake and driven slowly round over the sheaves to trample on the crop. Sometimes, the crop is also left on roadways for local traffic to pass over it.

Figure 3.3: Manual threshing of rice (left), and pulse (right)

- **Machine threshing**

This involves the use of simple hand or pedal driven threshers and powered machines like combine harvester. These machines can treat different kinds of grain (e.g. rice, maize, sorghum, beans, sunflowers, wheat, soybeans, etc.). It is equipped with a rotating threshing-drum (with beaters or teeth) and a stationary counter-thresher, these machines often have devices to shake out the straw and to clean and bag the grain. Whether self-propelled or tractor-drawn, these threshers are often mounted on wheels for easy movement to the field. The use of motorized threshers may require two or three workers.

Figure 3.4: Maize shelling using Sheller machine

III. Drying

Is the process of reducing moisture content from the crop. Grains drying are done before and immediately after shelling or threshing to ensure that the moisture is reduced to the recommended amount for safe storage. In roots and tubers, drying is done after grating or chipping if a farmer/processor is aiming at producing flour.

Things to consider during drying

- Produce should never be placed in direct contact with the soil.
- Place produce directly on the sun using a drying floor such as raised platform, a tarpaulin, layer of sacks or woven mats. Cribs can be used to dry cobs, pods, or seed head in humid areas.
- Keep produce away from farm animals, otherwise the produce may be damaged or eaten.
- Pulses are normally left in their pods, millet and sorghum are usually left on the seed head and maize grain is left on the cob. The reason for this is that in the "unthreshed" form, air can circulate more easily around the grain and so drying is more easily accomplished.
- Spread the produce evenly to allow uniform drying.

Figure 3.5: Produce are evenly spread on a canvass or dried by using cribs

Advantage of drying

i. Prevent contamination of fungi
ii. Ensure quantity, quality and safety
iii. Extends shelf life of produce

IV. Sorting and Grading

These are important post-harvest operations undertaken to remove foreign and undesirable matters from the threshed crops/grains/seeds and to further separate the grains/products into various fractions.

Sorting is the process of separating produce into groups with different physical properties. Physical properties include weight, size, shape and damage.

Figure 3.6: Manual sorting of agricultural crops

Advantages of sorting

i. To attract consumers
ii. To increase the quality of the crop
iii. To increase uniformity of produce
iv. To give better control over the fill weight
v. To enhance effectiveness of mechanical operation

Grading: Is the process of separating produce into groups of different quality properties/characteristics. Grading is the classification of material based on its commercial value, end usage (product quality), and official standards. Grading is necessary to avoid the further processing of blemished, spoiled, or products not meeting the quality requirements. Factors considered in grading include size, shape, maturity, texture, flavour and aroma, free from blemishes and contaminants, colour and conformity with legal standards. The quality of produce falls under four different aspects that include;

- Process suitability
- Consumers safety
- Conformity with legal requirements
- Consumers acceptance

Methods of grading

a) **Manual grading**: Produce are assessed and sorted by size, shape and quality. This is usually done by trained/experienced people.

b) **Mechanical grading**: This is done by machines where sorting is simultaneously taking place.

c) **Quality determination**: This is done by carrying out laboratory tests for confirming the produce quality.

Figure 3.7: Maize grading machine (left), and grading sieves (right)

V. Packaging

Packaging is a means of providing correct environmental conditions for produce during the length of time it is stored and distributed to various areas.

Figure 3.8: Packaging of roots and tubers

Good packaging material must be:

i. Made of substances which are safe and suitable for intended use
ii. Capable of preserving the quality of the produce
iii. Cheap and convenient in handling operations and storage
iv. Able to prevent spoilage during transit and storage
v. Clean and attractive
vi. Helpful in reducing the marketing cost

vii. Biodegradable/ or environmentally friendly
viii. Free from chemical residue
ix. Reusable, i.e. useful after the main use.

Importance of packaging:

i. It facilitates handling and distribution to more distant market
ii. It increases attraction of produce/ aesthetic properties
iii. It is embodied identification of company
iv. It involves the instructions on the package
v. It protects produce from contaminants and stress damages.

VI. Weighing

Weighing is the method of determining the mass of the crop produce

Factors to consider during weighing

a) The measurement must be correct and precise
b) Conduct the zero adjustment of spring scale or table scale before starting the measurement of weight
c) Conduct the measurement by putting the grain on the scale. Read the weight graduation after the indicator is stable. Read the weight in kg by round off to one decimal place by 100g.
d) After measurement, don't forget to deduct the tare weight, which is the weight of the bag/vessel used

Figure 3.9: Platform type weighing scale

Figure 3.10: Reading mechanism for platform type weighing scale

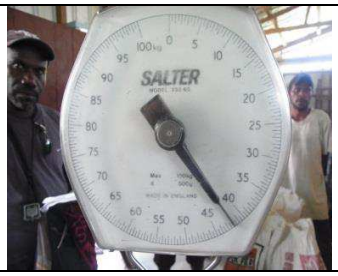


Figure 3.11: Hanging scale of 100 kg capacity

VII. Transportation

Generally transport marks the passage from one stage of the post-harvest system to the next (from field to threshing or drying site). It is important to transport produce on time and that the quality is protected during transport for example grains should be covered in case of rains. There are various means of transportation depending on availability of transport facility, distance and amount of

produce. This can be traditional such as carts, head carrying, motor bike and bicycles or modern such as tractors and trucks.

Things to consider when transporting produce

- Use of clean facility
- For grains, facility should be dry
- Don't mix produce with any chemical
- Make sure there is enough ventilation to avoid temperature build up
- If transport is done by cart, dropping of produce should be avoided

Figure 3.12: Carts

Figure 3.13 Head carrying

Figure 3.14: Power tiller

3.3.5 Selecting equipment for post harvesting

Farmers use different equipment and machineries for post-harvest operations depending on availability and skill of use. The commonly used post-harvest equipment and machineries are detailed in Table 3.1:

Table 3.2: Summary of tools, machines and equipment used at postharvest stage

Tools, machines or equipment	Purposes/uses
Chopper (knife, scissor, peeler, chopper slicer)	Chopping cassava, sweet potatoes and round potatoes.
Cleaners (brush)	To remove soil from root surface.
Cutting, slicing and dicing equipment (cutter, knife and slicer)	For cutting, slicing and dicing roots/tubers.
Shellers	Shelling of maize, groundnuts and sunflower
Destoner	Separates grain mass
Graters	Grating cassava
Chippers	Chipping cassava and sweet potato
Dryers	Drying and dehydration.
Filling machines	Filling of solid materials into containers and pouches.

Sieves and strainers	Sieving and straining
Harvesters (combine harvester)	For harvesting
Sampling probe	Collecting grain sample in the store/warehouse
Pallets	Carrying bags, sacks in the store/warehouse to prevent moisture from the floor
Packaging equipment (bags, boxes/crates)	Packaging of different produces.
Peeling equipment (knife, peeling machine)	Peeling and coring
Pulverizer	Simple machine that grinds to reduce particle size.
Sealing machine	Sealing the polyethylene bags.
Sorting equipment (cages, sorting tables, carts, sorting machine)	Grading food items on the basis of size, density or shape.
Threshers	Threshing grain and oilseed crops.
Weighing balance/scale	Weighing the produces.
Moisture meter	Measuring grain moisture content

3.3.6 Post-harvesting operations for different crops

Cereal grains

1) Maize:

i. Transport the harvested produce by using carts, recommended tracks or other means of transport,
ii. Pre-dry the maize cobs by spreading on mats, canvas or slabs,
iii. Shell the maize cobs by hand or by using shelling machine which are available at the market to obtain grains,
iv. Pre-sorting of defect cobs,
v. Thresh the produce manually or by machine,
vi. Winnow the shelled maize grains using bamboo tray or machine,
vii. Sort to remove foreign material, pieces of cobs, stones and diseased ones by placing the produce on sorting table or any other available means,
viii. Grade the sorted maize according to recommended grades,
ix. Re-dry to a moisture content of 13% (use moisture meter for confirmation),
x. Treat the dried maize with recommended pesticides at the right dosage against maize weevils and LGB, respectively.
xi. Pack the treated maize in the gunny bags (weighing 90 kg), and stitch firmly ready for storage.

NB: Hermetic storage does not require chemical treatment.

2) Sorghum and Millets

i. Transport the produce by using carts, trucks or other means of transport,
ii. Pre-dry the produce by spreading them on mats or canvas,
iii. Pre-sort to remove rotten panicles,
iv. Thresh the dried produce manually or by machine,
v. Winnow the threshed produce using bamboo tray or machine,
vi. Sort the produce manually or by machine to remove foreign material, pieces of spikelet, stones and rotten ones,
vii. Re-dry to 13.5 % (sorghum) and 14 % (millets) moisture content, (use moisture meter for confirmation)
viii. Treat the produce with recommended pesticides at the right dosage against weevils and LGB (Scania), respectively.
ix. Pack the produce in the gunny bags (weighing 90 kg) and stitch firmly ready for storage.

3) Wheat and Barley

i. Transport the produce by using carts, trucks or other means of transport,
ii. Pre-dry the produce by spreading them on mats or canvas,
iii. Pre-sort to remove rotten panicles,
iv. Thresh the dried produce manually or by machine,
v. Winnow the threshed produce using bamboo tray or machine,
vi. Sort the produce manually or by machine to remove foreign material, pieces of spikelet, stones and rotten ones,
vii. Re-dry to 14 % moisture content, (use moisture meter for confirmation),
viii. Treat the produce with recommended pesticides at the right dosage against weevils and LGB (Scania), respectively.
ix. Pack the produce in the gunny bags (weighing 90 kg) and stitch firmly ready for storage.

4) Paddy

i. Thresh the cut paddy by using sticks or pedal/hand driven machines,
ii. Winnow the threshed paddy by using bamboo trays or machine to remove non-filled grains and chaffs,
iii. Transport the produce by using available means of transport,
iv. Pre-dry the winnowed paddy,
v. Re-winnow the pre-dried paddy to remove non-filled grains

vi. Sun-dry or dry by using electric driers to 14% moisture content (use moisture meter for confirmation),

vii. Pack in the gunny bags (weighing 75 kg) and stitch firmly ready for storage.

NB: Combine harvesters can be used depending on their availability. This technology performs all the post-harvest operation; from threshing to packaging.

5) Legumes

This includes beans, soybeans, cowpeas, pigeon peas, field peas, chickpeas, bambara groundnuts and grams. Postharvest processes of legumes include:

i. Pre-dry the produce by spreading on mats, slabs and canvas,

ii. Thresh the dried produce by using sticks on mats/canvas/slabs,

iii. Winnow to remove chaffs,

iv. Sort to remove foreign material, stones, crushed ones and rotten produce,

v. Grade the produce based on recommendation,

vi. Dry the produce to 14% moisture content (use moisture meter for confirmation)

6) Root crops (cassava, sweet potatoes, round potatoes, yams and coco yams)

i. Cleaning and Sorting

- Clean produce by using soft brush to remove soil (if harvest is done on moist soil leave the roots until they dry for two or more hours),
- Remove rotten, cut, stunted and immature roots/tubers,
- Roots/tubers that are cut and stunted should be used immediately to avoid spoilage.

ii. Transportation

- Transport the root crop produces from the field to the pack house/homestead.

iii. Grading

- Grade according to variety, size and shape depending on market requirements.

Figure 3.15: Graded fresh sweet potatoes

iv. Packaging

Pack the produce in hard boxes (with holes) and plastic/wooden crates that allow air circulation and which can prevent bruises. This packaging equipment have smooth surface that are suitable for packaging and transportation to the market. Also aerated bags can be used. The weight of package should not exceed 20 kg. If aerated bags are used, the weight should be 60 kg.

For a farmer who intends to store the root produces for an extended time, curing process has to be performed.

v. Curing of roots and tubers

Roots and tubers have the ability to heal their skin wounds when held at relatively high temperature and humidity for a few days after harvest. At the same time there is a general strengthening of the skin. The term "curing" refers to the process of self-healing of wound, cuts and bruises with the development of new epidermal tissue called wound periderm. If roots and tubers are to be stored for long periods, curing is necessary.

Curing should begin as soon after harvest as possible, preferably within 12 hours of harvest and preferably near the place where the produce will be stored in order to minimize handling after curing. The process is carried out for 4 to 10 days at high temperature and a relative humidity. Roots and tubers should not be washed prior to curing and/or storage as this increases decay. If necessary, roots can be washed prior to marketing. Different conditions are needed for curing roots and tubers (Table 3.2).

Advantages of curing

i. To prevent the invasion of pathogens and decay,
ii. To limit the rate of respiration and water loss,
iii. To increase storage life of a produce.

Steps involved in the curing process:

i. Desiccation of several layers of surface cells at the site of the wound,
ii. Cells suberization (thickening of cell walls below the wound). The production of suberin and/or lignin and its deposition in cell walls;
iii. The formation of new cell (cork cambium); production of cork tissue in the bruised area.

The new cork tissue seals the cut or bruised areas and helps prevent the entrance of decaying organism while also reducing water loss.

Factors affecting the healing of wounds;

i. Temperature of the commodity
ii. Oxygen and carbon dioxide concentration within the commodity

iii. Humidity within the commodity

iv. The use of sprout inhibitors

Table 3.2 Curing requirement for different curing root and tuber crops

Crop	Temperature ^{0}C	Relative humidity (%)	Duration (days)
Potato	15 - 20	85 - 90	5 - 10
Sweet Potato	30 - 32	85 - 90	4 - 7
Yam	32 - 40	85 - 95	4 - 7
Cassava	30 - 40	90 - 100	4 - 4

Local procedure for curing

Select the area under a partial shade (curing pile should not be exposed to direct sunlight)

Pile the produces on the ground and cover them by a layer of grass at least 15 cm thick,

Cover the pile with a canvas tarpaulin or jute bags. (Plastic sheets should not be used),

Remove the cover after 4 days.

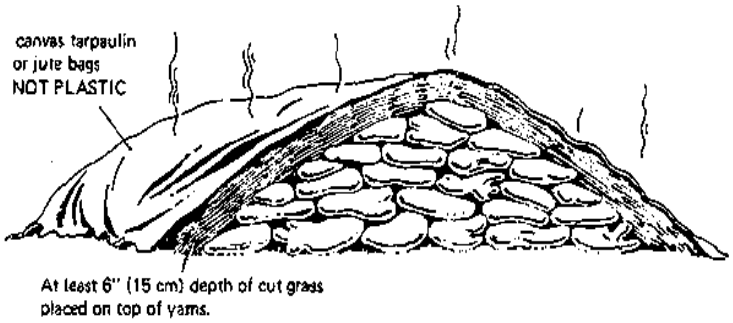


Figure 3.16: Local curing structure

7) Oil Seed Crop (sunflower, sesame and groundnuts)

a) Sunflower

i. Transport the produce by using carts, trucks or other means of transport,

ii. Pre-dry the produce by spreading on mats, canvas or slabs,

iii. Thresh the oil seeds manually or by machine,

iv. Winnow the produce to remove non-filled seeds and chaffs

v. Sort the produce to remove foreign material, stones and crushed seeds,

vi. Grade the produce based on recommendation,

vii. Re-dry produce to 12% moisture content (use moisture meter for confirmation),

viii. Pack the produce in the gunny bags (weighing 100 kg) and stitch firmly ready for storage.

NB: Treatment for sunflower against storage pest is very rare.

b) Sesame

i. Transport the produce by using carts, trucks or other means of transport,
ii. Pre-dry the produce manually or by machine,
iii. Thresh the oil seeds manually or by machine,
iv. Winnow the produce to remove non filled seeds and chaffs,
v. Sort the produce to remove foreign material, stones and crushed ones,
vi. Re-dry produce to 12% moisture content (use moisture meter for confirmation),
vii. Pack the produce in the gunny bags (weighing 100 kg) and stitch firmly ready for storage.

c) Groundnuts:

i. Pre-dry the groundnuts on slabs,
ii. Detach the pods from the plant,
iii. Thresh ground nuts using groundnuts threshing machine or by hands,
iv. Winnow the groundnuts to remove non filled nuts and chaffs,
v. Sort to remove foreign material, stones and crushed ones,
vi. Re-dry to 12% moisture content (use moisture meter for confirmation),
vii. Pack the produce

3.3.7 Facilities used in Post-harvest Operation

A. Slabs:

These are raised platforms made of concrete or cement for carrying post-harvest operations of cereals, legumes, oil seeds and dried root crops. The activities carried out on slabs include:

- Drying by spreading the produce on the slab
- Threshing of produce by detaching the produce from their mother plant
- Winnowing, sorting, grading and packing.

B. Pack house/pack shade

This is the structure protected from weather for both, product and personnel. This structure is mainly designed for receiving crops/ fresh produce from the field as a temporary storage. However, they are used for other post-harvest operations such as;

- Precooling
- Cleaning
- Sorting, grading and packing.

C. Laboratory

This is a facility used for confirming the produce quality and quantity using standard procedures and indices. It involves the use of some reagents and tools. For example dried beans, test for uniformity of colour and size, standard weight of 100 grain legume and moisture content can be tested and confirmed.

3.3.8 Procedures for treating grains with chemicals

- Read instruction on the label of chemical container/package
- Prepare location and equipment that will be used
- Measure your grains to know the amount that will be mixed with a chemical (kg)
- Place grains on canvas or clean floor
- Measure recommended amount of chemical as per instruction in a label, depending on amount of your grains
- Mix chemical with grains by using a spade until they are well mixed

NB: Consider withdraw period before consumption or marketing of grain (read the label clearly) and wear protective gears.

3.3.9 Adjusting crop yield for storage purposes

Formula: $$W_A = \frac{W_H \times W_H\%}{W_S\%}$$

W_A = Adjusted yield
W_S % = Percent dry matter at storage
W_H% = Percent dry matter at harvest
W_H = Weight at harvest in Kg.

Example: How to calculate yield adjustment:

Maize Crop

i. Maize are harvested at moisture content (MC) of about 20%
ii. Maize grains are dried to 13.5% moisture content.
iii. If yield at harvesting was 3,850 kg/ha at 20% MC,
iv. Adjusted Yield at 13.5% MC will be calculated as:
v. Use 100% - MC, as dry matter: Given

Percent dry matter at storage WS % = 86.5%

Percent dry matter at harvest W_H% = 80%

Weight at harvest W_H = 3,850 kg

Adjusted yield W_A = ?

Formula: $W_A = \frac{W_H \times W_H\%}{W_S\%}$

$W_A = \frac{3850\ Kg \times 80\%}{86.5\%}$

W_A = 3561 kg/ha

Table 3.3 Moisture Content during harvesting and storage for the various crops

Crop	Moisture Content (%)	
	During Harvest	During Storage
Maize	20	13.5
Paddy	20	14
Sorghum	16	14
Millet	16	14
Wheat and Barley	20	12
Legume	16	11
Sunflower and sesame	25	11-12
Ground nuts	20	11

CHAPTER FOUR

4.0 STORING THE CROP PRODUCE USING RECOMMENDED METHODS

4.1 SELO: Storing the crop produce using recommended methods

4.2 CBLA

i.	Understanding basic concepts related to storing of different crops
ii.	Explaining essential crop storage activities for crop stored
iii.	Treating crops during storage

Table 4.0: CBLA Matrix/Framework

Sn	CBLA	Time in minutes	Participatory/ Activating Methods	Facilitation Materials/ Resources	Guidance Tools	Integrative Assessment Methods
a)	Understanding the storage structures for crop storage i. Defining terms related to storing of different crops storage ii. Identifying the various crop storage structures *(traditional and modern/ improved structures*) iii. Explaining the types of crop storage structures iv. Describing the features /criteria to consider for various best crop storage structures v. Describing conditions necessary for good storage facility.	**60**	-Field visit -Demonstration -Discussion -Brainstorming -Lecturette Jig saw	-Multimedia (Video, projector, TV) -White board/black board/chalk -Flip charts/maker pen	-Logbook for reflection -Portfolio	- Written Test - Assignment
b)	Understanding the essential crop storage activities for crops stored i. Defining terms related to management of crop produce in a store (Fumigation ,fumigants) ii. Explaining causes of loses in crop storage iii. Carrying out essential storage activities before, during and after crop storage	**300**	Site visit - Discussion - Jig saw - Demonstration	- Storage structure/tools - Flip charts/maker pen - White/chalk board - Multimedia (Video, projector, TV) - White /black board - Flip charts	- Portfolio - SSAF	- Assignment - Written test
d)	Treating of crops during storage i. Describing the fumigation process ii. Identifying the types of fumigants to be used iii. Explaining the advantage and disadvantage of fumigants iv. Explaining factors for success and failure for fumigation	**240**	-Demonstration -Site visit	-Multimedia (Video, projector, TV) -White /black board -Flip charts	-Portfolio -SSAF	- Competence test - Written test - Assignment - Project work

TRAINING NOTES

4.3 Basic Concepts Related to Storing of Different Crops

Storage is the phase within the post-harvest system during which crops are stored for future use. Storage is the last step in the storage process where the grain is stored in a device or a special place. The storage process consists of a range of crop conservation activities from harvesting to the barn. Farmers must comply with the principles of good crop production during and after harvesting to avoid crop losses. The produce can be stored for varying periods to ensure proper and balanced public distribution throughout the year.

4.4.1 General Criteria for Best Storage

For successful produce storage essential activities are to be followed to ensure quality that will reduce storage losses. Reduction of losses contributes to reducing food insecurity for the country. The following criteria should be considered for best storage:

i. The produce must be thoroughly cleaned and graded
ii. Dried to the safe storage moisture level of 10-12 % for food grains and 7-9% for oil seeds (on wet basis) for a safe storage period of 6-12 months
iii. The produce should be free from damage by insects and fungi
iv. Storage structures should be properly maintained, cleaned and disinfected
v. Structures should not permit contact/exchange with outside humid air
vi. Structures should be constructed in the coolest part of the house/ farm
vii. Prepare a warehouse by cleaning, maintaining or building and spraying
viii. Leave a space of one meter between pockets and wall to facilitate cleanliness and control
ix. Allow air circulation
x. Perform regular inspection of crops and warehouses to check if action is needed.

4.4.2 Storage Methods and Structures

There are two categories of storage methods commonly used in Tanzania. These are ***traditional*** and ***modern*** storage methods.

Requirements for an ideal storage facility

A good storage facility should meet the following conditions:

i. It should provide maximum possible protection from ground moisture, temperature, rain, insect pests, moulds, rodents, birds etc.

ii. It should provide the necessary facility for inspection, disinfection, loading, unloading, cleaning and reconditioning
iii. It should be economical and suitable for a particular situation
iv. It should have provision for application of pesticides through spraying or fumigation
v. It should be located far away from possible sources of infection such as kilns, flour mills, bone crushing mills, garbage rumps, tanneries, slaughterhouses and chemical industries
vi. It should be located at a convenient place to easy receive and transport food grains.

A. Traditional farm/village storage methods

Traditional storage methods involve use of storage structures made from available natural resources in the area such as grass, trees, poles and soil. These storage methods have been used for many years in different parts of Tanzania and have been changing over time due to various changes that occur in the environment. Traditional storage methods vary from one location to another due to their type, climate, culture, human economy, availability of building materials and incidence of crop disruptions. Traditional storage methods are on the decline due to changes like:

i. Use of seed and modern equipment in agriculture
ii. Increase in crop production
iii. Inadequate availability of natural building material
iv. Ease of access to modern equipment
v. Loss of skills to make traditional structures
vi. Crop demand for consumers

Traditional storage methods include:

- **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 produce 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 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.

Figure 4.1: Aerial storage

ii. Storage on the ground or on drying floors

Most of crop produce are normally stored on the ground temporally for drying purpose or while waiting the next step of post-harvest handling. This method is not recommended as the grain is exposed to pests, domestic animals and the weather.

iii. **Open timber platforms**

A platform consists of 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 level. They are usually rectangular in shape. The produce is stored on platforms in heaps, woven baskets or in bags.

Figure 4.2: Open timber platform

Benefits and limitations of temporary storage

i. Cheap to construct
ii. Gives a farmer enough time to prepare for the next step
iii. Materials are locally available
iv. Does not require skilled personnel
v. Gives the room to do treatments to the produce
vi. Allows the farmer to perform grading and sorting

Limitations of temporary storage

i. Exposes the produce to theft and damage by insects
ii. It is not weather friendly
iii. Exposes the produce to contaminants
iv. It is limited to small scale production
v. The construction material is prone to rotting

- **Long-term storage methods**

In traditional long-term methods, the produce may be stored in cribs**, c**alabashes and earthenware pots;

i. **Storage cribs**

In humid environments, where produce cannot be dried adequately prior to storage, cribs are used to temporarily store the produce while allowing air circulation to dry them adequately. Cribs are usually constructed entirely out of locally available plant materials like timber, reeds, and bamboo. However, under prevailing climatic conditions most plant material rot quickly, and most cribs have to be replaced every two to three years

Figure 4.3: Storage cribs

ii. **Calabashes and earthenware pots**

These are small capacity containers, most commonly used for storing seed and pulse grains, such as cowpeas. Because of the small opening they have, 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 bung reinforced with cloth.

Figure 4.4: Calabashes and earthenware pots

iii. Metal or Plastic Drums

Drums are often used as storage containers in the house and serve notably for the storage of cereal seeds and pulses. Plastic drums are used intact or after having the upper part cut off to facilitate loading and unloading. Otherwise, plastic lends itself poorly to adaptation because it is relatively weak, though a lockable outlet can be added. If the lid is tight fitting and the drum is filled with grain, any insects present will deplete the oxygen in the drum and die. Metal drums can be adapted for domestic grain storage in a similar way. A removable lid permits easy loading; but it is also possible to weld half of the lid to the rim of the drum and provide a riveted hinge on the remaining half of the lid so that it alone can be opened. Fitted with a padlock, such a modified drum is more secure. To make a store of greater capacity, two metal drums can be welded together end to end and fitted out as described above. Well modified and/or fitted with gaskets, metal drums can also be made airtight. Inaccessible to rodents, efficient against insects, sealed against entry of water, drums make excellent grain containers.

Figure 4.5: Hermetic plastic and metal silos

B. Improved, modern storage structures

As a result of various developments occurring in agriculture, traditional storage structures must be improved to meet the needs. The use of improved storage structures will depend on the availability of construction materials, local weather conditions and crop disruptions in the area.

Features of improved structures:

i. Easy to build
ii. Low cost
iii. Easy to clean
iv. It is solid and durable
v. It does not pass water easily

Figure 4.6: Improved structures

Improved, modern storage structures are constructed by using industrial materials such as timber, cement, tin tiles and canvas. They also involve the use of structures with airtight chambers like silos and cocoons, and structures that allow air penetration like warehouses. In some of these structures loading belts and bags, sewing machines, weighing machines and moisture metres are employed. Examples of

this type of infrastructure include silo, air bags and brick barns. **Benefits** of modern storage structures over traditional are:

i. They are durable
ii. They are easy to clean, import and produce
iii. They are easy to control discomfort due to climate change
iv. They are easy to control thieves and fire disasters
v. They can store large quantities of produce
vi. They allow reducing the excessive use of chemicals
vii. They have enough space for supervision and control
viii. They reduce crop losses

The **limitations** of modern storage structures are;

i. High investments are required to build and operate the structure. Hence they are mainly owned by large farmers, traders, cooperatives, crop boards and large farms.
ii. Uncoated metal rusts quickly in hot and wet areas
iii. Special equipment is required to cut and weld the metal
iv. Synthetic silo is prone to damage by insects if stays long

i. Metal Silo

This is a modern storage structure made from a special corrugated iron. It is made in the shape of a cylinder that is mounted on top and bottom leaving the small mouth to insert the grain on the upper side and the part of the grains on the bottom. Silos can be in small and medium size depending on demand. The manufacturing cost depends on the size of the silo.

Advantages of metal silos

i. Lasting for more than 20 years
ii. It controls discomfort and thieves
iii. It is easy to make
iv. It is easy to export
v. It reduces the cost of packaging
vi. It reduces costs of pesticide

Procedures for using silos during grain storage

(a) Before filling the produce into the silo:

i. Check for leakage of rainwater and sufficiency of drainage facilities
ii. Clean the facility and environment
iii. Assess the capacity of the facility
iv. Make security and firefighting arrangements and
v. Repair the equipment when necessary

(b) After receipt of produce

i. Inspect the quality of the produce and its quality in terms of levels of insect infestation and cleanliness
ii. Measure the moisture content of the produce
iii. Sort to remove the damaged grains
iv. Check and record the weight received

(c) During storage of produce

i. Fill the produce into silos
ii. Seal the silo after filling the produce
iii. Maintain of cleanliness
iv. Inspect presence of insects, rats and mites at fortnightly intervals
v. Watch for advancement in deterioration, if any
vi. Pesticides treatments is necessary based on observations
vii. Ensuring disposal where called for
viii. Sort the grains to remove the damaged and broken grains.

Figure 4.7: Silos

ii. Cocoons

This is the hermetic storage container that consists of two plastic halves that are joined together with an air-tight zipper after the cocoon is loaded with sacks of the commodity to be stored. Cocoons have different volumes from 50 kg to 1 metric ton to continue.

Cocoons reduce the flow of both oxygen and water between the stored grain or seed and the outside atmosphere. When properly sealed, respiration of grain and insects inside the bag reduce oxygen levels from 21% to 5%. This reduction reduces live insects to less than 1 insect/kg of grain without using insecticides - often within 10 days of sealing. The stabilized moisture inside the cocoon prevents wetting and drying of grain.

Advantage of cocoon

i. It is easy to move
ii. It has the ability to store large quantities of produce
iii. Can be used to store seeds as it extends the germination life of seeds,
iv. Controls insect grain pests without chemicals
v. Reduces use of pesticides hence storage cost.

Limitation

i. Cocoons made from canvas material are prone to damage by termites and rodents
ii. Becomes brittle if exposed to sunlight for longer time
iii. May be carried by wind if not well tightened
iv. Can be damaged by sharp objects

Procedure for using cocoons

i. Inspect the bags and make sure that there are no perforations
ii. Fill the produce into the bags
iii. Seal and tie tightly the bags
iv. Set the platform 5 cm above the ground
v. Place the sealed bags on the platform
vi. Make sure the platform is above the ground (5cm)

Figure 4.8: Hermetic cocoons (above), and hermetic bags (below)

iii. Warehouse

Warehouses are special houses built by using bricks for storage purposes. The warehouse should incorporate the following features:

i. Protect the stored food from attack by rodents and bird
ii. Keep grain dry and cool
iii. Facilitate the use of insecticides
iv. Be easy to clean and maintain
v. Be using components which are readily replaceable or repairable
vi. Provide good working conditions

Essential features for a good warehouse

Basic components of a warehouse include floor, walls, roof, one or more entrances, ventilators and artificial lighting as explained bellow:

Location

i. The ground where a warehouse is to be constructed should be resistant to compaction and have good drainage.
ii. The ground should be levelled, slightly raised above the surrounding area and should not be prone to flooding
iii. Warehouses should be sited as near as possible to a main road for easy access and movement of stocks
iv. There should be enough space for additional warehouses and utility buildings, easy movement and manoeuvring of vehicles around it
v. If possible, the long axes of warehouses should be oriented East-West so that the side walls are least exposed to the sun, and temperature variations inside are minimized
vi. Warehouse should be away from residential areas, market places and other working areas to avoid effects of some dangerous warehouse operations like fumigation as the fumigant gases are lethal to human beings
vii. It should be located far away from possible sources of infection such as kilns, flour mills, bone crushing mills, garbage rumps, tanneries, slaughterhouses and chemical industries
viii. Should be located at a convenient place from where it is easy to receive and discharge food crops

Floor

i. Must be able to bear the weight of the grain which will be stacked upon it
ii. Must be impermeable to ground water
iii. The floor level must be sufficiently above ground level to ensure that water will not enter the warehouse, even after the heaviest rainfall that can be expected
iv. Should be easy to clean
v. Should not have cracks as they will make storage hygiene difficult and hide pest

Walls

i. Should be smooth and free from projections to facilitate cleaning of the store and avoids interference with other operations as well
ii. Should be painted white, on the inside to facilitate the detection of insect pests, and on the outside to help keep the warehouse as cool as possible
iii. Should prevent damp rising and causing damage to the structure and its goods

Roof

i. It should not allow water leakage
ii. It should keep rain off the structure and provide shade during the heat of the day.

To achieve this, the roof should overhang the gables (by 0.7 to 1.0 m) and the eaves (by at least 1 m) to ensure that rainwater is shed away from the walls. Use of gutters and drainpipes is not recommended as they may become blocked or assist rodents entering the warehouse. The overhang also helps to keep walls cool and protects ventilation openings from rain.

Ventilation

Warehouse should have ventilation openings necessary for:

i. Allowing the renewal of air and reducing the temperature in the warehouse
ii. Allow some light to enter

Ventilators at the eaves that can be opened and closed easily, fitted on the outside with anti-bird grills (2 cm mesh). Such openings should be placed under the eaves and not located too low down in order to prevent the entry of water, rodents and thieves.

Doors

i. There should be at least two doors to enable rotation of stocks on a 'first in, first out' basis
ii. Should be sufficiently large enough (at least 2.5 x 2.5 m) to allow easy access for moving bags in and out
iii. Should be close fitting enough to prevent rodent access
iv. Should shut securely with a padlock or other locking device
v. If swing doors are fitted, they should open outwards in order not to reduce the storage capacity of the warehouse
vi. Choose doors that are large (preferably metal double sliding doors)
vii. Protect the doors from rain by an extension of the roof or a separate cover.

Figure 4.9: Warehouse

Conditions necessary for good storage

a) **Before storage**

i. For grains to be stored
   - Ensure that the crop going into store is in good condition; i.e. well dried to the recommended moisture content, free from insect pests and mould, well cleaned and sorted.

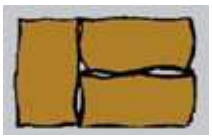
ii. For the warehouse
   - Warehouse should be in good condition;
   - Clean and all the old harvest is removed,
   - Provide protection against rodents, birds and browsing domestic animals like poultry,
   - Prevent water leakages and keep it free from cracks and crevices.

iii. Make sure that essential items of equipment are available and in good condition
   - Pallets on which bag stacks are to be built
   - A set of weighing scales to weigh grain in and out (these weighing scales must be regularly calibrated)
   - A sampling spear to check grain quality
   - Brooms used to keep the store clean
   - Tarpaulins that can be used to cover bag stacks to prevent insect infestation moving from one stack to another and as a base on which to do grain conditioning operations
   - Spare sacks to replace any that are torn and to contain spilt grain that has been swept up from the floor
   - Ledgers to record the movement of grain in and out of the store
   - It is also useful to have a moisture meter to check moisture content and a torch for the inspection of dark areas in the store.
   - Clean the store exterior and the area around by removing all vegetation close to the exterior so that rodents and insects cannot hide, nor have any nearby trees where rodents can jump from and then enter the store via roof eaves etc.

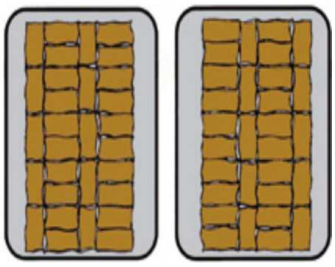
b) During Storage

Lay out the pallets with a gap of 1m from the store walls (make sure the pallets are clean, level and have no protruding nails).

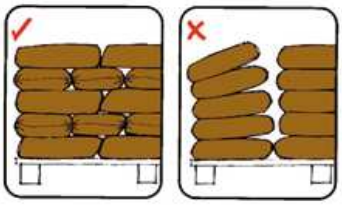
i. Build the bags into a stack on the pallets using "a key system" with units of three bags.



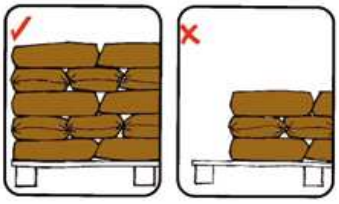
ii. Build the first complete layer of sacks on the pallets using units of three. The position of sacks in the second layer should be in the opposite direction from the first.



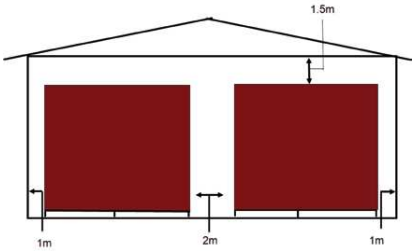
iii. Side view of a bag stack built using the 'key system' (left hand side), and one where the key system has not been used (right hand side)



iv. Sacks should be positioned up to the edge of the pallets but not overlapping.

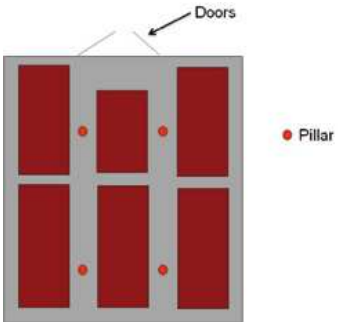


v. The bag stack should be built at least 1 m away from the walls of a store. This allows easy inspection, prevents moisture ingress from contact with the wall and facilitates fumigation treatments since a gas-tight sheet can be placed over all sides of the stack.



vi. There should be a gap of at least 1.5 m between stacks, and 2 m between stacks where this space is the main gangway leading to the doors.

vii. The bag stack should be built clear of any pillars, otherwise it will not be possible to place a fumigation sheet over the stack.



viii. The bag stack should not be built too high and not closer than 1.5 m to the store roof beams so that staff can work on top of stacks

ix. When using jute or sisal bags the bag stack can be built to around 18 to 20 layers; if higher, there is a risk to stability, and it is difficult for storage workers.

x. When using polypropylene or plastic bags the stack heights must be lower as they are less stable than jute or sisal bags

xi. At about the 12th layer, the bags should be moved inwards by one bag width at each layer so that the sides will slope inwards like a pyramid

xii. No bag stack should ever be higher than it is wide, otherwise it will be unstable.

4.4.3 Causes of Losses during Crop Storage

Maintaining good quality of the stored crops depends on the on-farm postharvest handling practices. Proper and timely harvesting and postharvest handling techniques and practices minimize losses during storage and maintain the good quality of the produce. Carefulness at this stage is far more cost effective than attempting to minimise losses and upgrade quality later in the warehouse because at the warehouse there may be no equipment or one has to pay for equipment and labour to re-perform the practices needed and large amounts of grain may be lost in the process.

a. Physical factors

Poor harvesting and postharvest handling practices which include:

i. Untimely harvesting resulting in pest and mould infestation in the field

ii. Inadequate drying resulting in moisture levels that are too high for safe storage.

iii. Inadequate cleaning and sorting lead to the accumulation of foreign matters such as stones, broken grain, plant material from harvesting such as husks, pods and dust produced during threshing. Presence of foreign matters in the grains facilitates mould and pest infestation.

iv. Mechanical damage during handling: Rough harvesting and handling of root crops may lead into damage in root crop hence affect its storage. On the other hand, use of improper tools during threshing may result in high grain breakage. Broken grains are much more susceptible to attack by moulds and by insects.

v. Poor storage structures: Cracks and crevices in storage places provides insects a home to lay their eggs, which can remain from one season to another. Leaking roofs allow water to enter the store causing additional moisture to the stored crops and leading to mould development.

vi. Inadequate knowledge on good storage practices and poor store management.

b. Environmental factors.

High relative humidity, temperature and oxygen in the store facilitate insect multiplication and mould growth during grain storage, which eventually affects the storability of the grain. Temperatures between 25 to 35 °C and relative humidity (RH) above 70% create favourable conditions for the rapid growth of most storage insects. These conditions increase pests' activities including grain consumption, reproduction and respiration leading to heat and moisture generation and ultimately to grain losses. Moisture development in the stored grains activates mould development leading to the production of mycotoxins. In addition, mould causes dry matter loss, odour, and a loss of nutritional value.

However, at temperatures lower than 13 °C or higher than 40 °C, insects tend to lower their activity, migrate, or eventually die. Also, majority of mould grows at temperature between 25 °C and 30 °C. It is recommended to store grains at Relative Humidity below 60% and with a moisture content of 13.5% for maize and 14% for sorghum and millets and legumes/beans.

c. Oxygen and Carbon dioxide levels

Higher moisture and oxygen availability increase the grain respiration rate and generate heat, carbon dioxide, and enzymes, which break down the starch, proteins, and lipids in grain.

d. Socioeconomic factors

The adoption of different storage structures also depends on socioeconomic factors, such as the farmer's family size, land holding size, required grain storage duration, off-farm income, road accessibility, market price of grain, and grain safety during storage. Usually large families have a greater demand for grain consumption and, thus, could more readily adopt better grain storage practices. Farmers with a relatively larger land holding could afford new storage technologies compared to those with a small farm area. Farmers having off-farm income have more financial resources at their disposal to invest in effective storage technologies. The higher market price of the good-quality grain after a few months of storage provides justification for farmers to spend more to store their grain for minimal loss or to preserve quantity and quality.

4.4.4 Management of Stored Crops

After arranging the grain sacks in the store make sure that the store is kept clean and tidy, its structure kept in good condition and aired wherever necessary to minimize losses during storage. The following are the essential activities for managing the stored crops;

a. Cleaning

Clean the store daily at the end of each day. Sweep from the back of the store towards the front so the dust will go out through the door. Carefully clean all cracks and crevices. Make sure all debris is removed. Each week sweep the walls, stack surfaces and, if possible, roof beams to remove all dust and debris. Start at the top and work downwards.

b. Inspection of the grain in the store

It is important to inspect the inside of the store. Below are some important tips for inspecting grains during storage.

i. At the start of each day check the store for signs of water leakage, check the floor and tops of bag stacks for signs of damage (rodent or insect damage with e.g. grains under or around pallets).

ii. Check for holes in the bags that need to be repaired.

iii. Check for insects in the store, inspect for moving insects in the late afternoon (16.00 h), check the 'ears' of bags and crevices between bags, listen for the sounds of insects eating grain, and use a torch to inspect the dark areas of the store.

c. Routine inspection of the store structure

It is important to check the outside of the store and repair it as necessary.

i. Each day the outside of the store should be checked for problems, and repairs should be undertaken as soon as possible.

ii. Inspect for problems and check for insects.

d. Store aeration

To minimise cross-contamination (e.g. with non-food grade chemicals), insect cross-infestation etc., make sure that:

i. Stocks are placed orderly in a dry and clean store, using clean and repaired pallets
ii. Crops are stored completely separately from other non-food goods; materials such as pesticides, fertilizers, cleaning chemicals and cements are not placed in stores that are being used for food
iii. Any damaged, rotten or spoiled grain should be segregated and stored separately
iv. Different commodities, different consignments (new and old) are placed in different stacks, i.e. separated in batches based also on the time of their reception in store, as far as the available space will allow.

e. Fumigation

Fumigation is one of the most effective techniques of pest control. In fumigation, an affected area is completely filled with fumigants (gaseous pesticides) to asphyxiate the pests. Fumigation is needed if insects are found on the grain during routine inspections. It is done to prevent the insects from causing serious damage to the stock. Fumigants are gaseous pesticides that control pests in agricultural fields, structures like buildings and apartments, storage houses and various other sites. Fumigants are generally biocide chemicals that can kill/injure living organisms with which they come in contact. Some fumigants also form parts of volatile organic compounds (VOC) which are dangerous compounds and infamous for their contribution in the creation of smog. Sulfuryl fluoride, formaldehyde, methyl bromide, chloropicrin and iodoform are some of the most popular examples of fumigants. Of these

fumigants **phosphine and methyl bromide** are the principal fumigants available for protecting stored products against insect and other pests.

Advantages of fumigants

i. If done properly, because of its wide spectrum pesticides, fumigation does kill all species and life stages of insects and rodents that are likely to be found in the structure being fumigated.
ii. Fumigants, being gases, penetrate into building's nooks and crannies, including the galleries of insects that infest interior wood, which cannot be reached by pesticide sprays and dusts.
iii. Pests are rapidly killed, and the fumigant gas does not leave unsightly, odorous, or hazardous residues if the site is properly aerated after fumigation.

Disadvantages of fumigants

i. Fumigants are broadly toxic and hazardous to use, and thus fumigations must be done by highly skilled and experienced, licensed fumigators.
ii. Because space fumigation is done successfully only in enclosed spaces, structures or sites to be fumigated must be tightly sealed.
iii. All humans and other non-target organisms must leave the area until the fumigation period is over, and aeration has been completed.
iv. You should also remove items that may be damaged by the fumigants.
v. Fumigation may cost more than other methods of pest control.
vi. Fumigants leave no protective residues, and pests may re-infest the fumigated site immediately after treatment.
vii. Corrosion is a real concern when fumigating with metal phosphides.

Characteristics to consider when selecting fumigants

i. The fumigant's volatility and penetration power
ii. The fumigant’s corrosiveness, odour, flammability, or explosive potential
iii. Warning capabilities and detection methods
iv. In the case of commodities, the fumigant’s effect on seed germination and quality of the finished or processed product
v. Decomposition time of the fumigant chemical or its residues
vi. Disposal of spent materials or containers
vii. Availability of the product of choice, ease of application, and cost.
viii. Season of year, weather, and climate

Factors contributing to successfulness of fumigation

Several factors are important in assuring successful fumigation

i. Grain should always be level in the bin to let the fumigant penetrate evenly.
ii. Any surface caking or crusting should be broken up and removed
iii. Grain temperature should be 60°F or higher to ensure proper vaporization
iv. Possible leak points such as cracks or holes in the bin should be closed before fumigation since leakage may result in under treatment and poor control

Causes of fumigation failures

Fumigation failures can usually be attributed to one or more of the following factors:

i. **Insufficient fumigant**

A fumigant's efficiency depends on attaining a lethal concentration in the grain. Results will not be satisfactory if less than the recommended dosage is used, or if the fumigant is applied under unfavourable conditions.

ii. **Storage structure**

Leaky bins will not retain fumigants long enough to kill the insects. The depth of grain also affects fumigation's efficiency. In general, the greater the surface area of the grain in relation to bulk, the greater the difficulties in adequate fumigation. As a result, flat storage bins require higher dosages than do round silo bins. Also, storage structures with a large amount of space over the grain are difficult to fumigate effectively because large amounts of gas escape into that space.

iii. **Moisture**

As moisture content increases above 12% a proportionately higher dosage of fumigant is required. It is difficult to effectively fumigate grain having surface moisture content of 15 to 20% because the fumigant's vapours will not penetrate the moist layer.

iv. **Temperature**

During fumigation, the gas quickly assumes the temperature of the grain. In general, fumigant activity increases as temperature increases. However, if grain temperature reaches or exceeds 46 °C, the fumigant may vaporize very rapidly and escape from the bin before accomplishing the job. On the lower end of the spectrum, stored grain insects are inactive at temperatures below 15.6°C. Fumigation should be delayed until the grain temperature increases.

The process of fumigation

To control insects at all life stages the only option is to fumigate in a gas-tight storage. Cool grain temperatures require a longer fumigation period. Aeration fans fitted on gas-tight silos provide various benefits including a shorter ventilation period following fumigation. The total time required for effective fumigation ranges from 10–17 days, accounting for the minimum exposure period, ventilation and withholding period. This highlights the importance of monitoring grain regularly and at least 17 days before out-loading to allow sufficient time to fumigate if required. Fumigation is a multi-stage procedure.

Step 1

- The first step involves preparation. The infested area that needs fumigation is covered with a tarp or tent to create a sealed environment. Fruits, vegetables, food, and medications that are not enclosed in glass or metal packaging with the manufacturer's original air-tight seal intact must be inserted into special bags provided by the fumigator company.

Step 2

- The second step is the main stage in which the actual fumigation is performed. The fumigant is released into the affected space. This space is then contained for a specific period (a couple of days, usually) with forbidden entry for individuals and their pets. This furlough allows the fumigant gas to percolate through the space in an effort to obliterate the infestation

Step 3

- The third step involves preparing the space to be used in its normal way. This stage involves ventilation. The space is ventilated so that the toxic gases have a way to escape from the space. After all, the space must be reclaimed for normal living.
- For a fumigation to be successful, the gas concentration needs to be kept for sufficient exposure time to kill all insects at all life stages. When the fumigation is complete, fresh air is forced through the grain to remove the fumigant. Care must be taken that the storage structure is sealed well before fumigation. Leaks present in the storage structure, whether a silo or warehouse, will invariably result in low fumigant concentrations that fail to kill the more resilient insect pests. In the event of an incomplete kill, PH3-resistant insects continue to produce offspring, thus creating a population of insects that are resistant to the fumigant.

f. Record Keeping for Stored Produce

Each storage facility must exercise due care in protecting and accounting for the supplies and food aid entrusted to it. The complexity of requirements will vary, depending upon the size of the facility, the nature of the goods in storage, its position in the logistics chain, and the reporting relationships for accountability. Basic operating standards and controls are, however, essential for good commodity management. Maintaining records of all incoming and outgoing stock, and stock on hand is essential:

- The **Stock Control Ledger** provides a chronological picture of receipts and issues, source or destination, quantities and item descriptions. Each entry is cross-referenced to the corresponding official receipt/issue voucher, release authorization, truck waybill or other documents which are kept on file to substantiate the action taken.
- A **Store Card** is established for each type of goods or commodity stored in the warehouse. All receipts and issues are recorded, providing a complete history for the item and the current total balance on hand.
- A **Stack Record Card** is affixed to each stack in the warehouse, showing the receipt and any issues of the goods in the stack, and the balance on hand. The reverse side of the card may be used to record treatments administered to the goods in the stack.
- A **Store Inspection Report** is completed each time the Chief Storekeeper inspects the warehouse.

Record Keeping Procedures

a. Use Stock Control Ledgers, Store Cards and Stack Record Cards.
b. Record all receipts, issues and balance on hand. Retain a copy of the receipt/issue voucher or waybill for verification.
c. Record all inspections and pest control treatments.
d. Verify records by conducting a physical stock count at least every six months.
e. For any stocked item lost or disposed of, record the quantity, and an explanation of the loss or the reasons for disposal and the method.
f. Submit a Monthly Summary to the senior official responsible for warehouse operations.

Receiving, handling and issuing stores

Ideally, larger warehouses should have separate doors and work areas for receiving and issuing supplies. This arrangement will eliminate any confusion and potential scheduling problems when these activities occur simultaneously. Every consignment arriving at a warehouse must be counted and inspected

carefully as the goods are being unloaded. Look for damaged packaging or commodities, and check for losses to identify:

- Sacks with holes, or split bags
- Broken or partially open crates
- Dented, buckled or leaking drums or cans
- Signs of wetness or stains on the surface of bags or cartons, or
- Signs of insect infestation.

Important issues storekeepers should check

i. The quantities received should agree with those listed on the waybill, stores requisition or packing list. Where tampering is evident, carefully check the contents of packages for missing items. Weigh sample bags of bulk commodities to confirm unit weights. Take random samples of commodities to check for quality, when appropriate.

ii. Record the number of units and/or the weight of the goods received and any amount which has been damaged or lost. Submit consignment receiving reports to the appropriate authority or agent, noting damage, shortage, excess or non-conformance, quantities, conditions and any extenuating circumstances. Initiate insurance claims and follow up on claims documentation where necessary.

iii. Instruct and supervise porters handling goods in the warehouse, to ensure that the goods are moved and stored efficiently with minimum damage. Never load or unload in the rain. Provide forklifts and/or conveyors with trained operators for large, heavy consignments. Use trolleys if available. Goods must not be dragged along the floor, dropped or thrown. Do not permit porters to use hooks which damage packaging and bags.

iv. Only authorized officials may sign a written release order to issue supplies from storage. On receipt of a release order, the storekeeper confirms that the supplies are on-hand and supervises their turnover to the receiver's agent taking delivery.

v. Stored goods are issued on a “first-in, first-out” (FIFO) base, i.e., the stores received first are issued first because they have been stored for the longest period. This rule is applied consistently, except for usable damaged goods, which are always issued first, regardless when they arrived. Record the issue in the warehouse records.

vi. A Store Requisition Voucher is prepared in three copies for each release order, with the receiver's agent signing to acknowledge receipt of the goods. Two copies accompany the issued

consignment to their destination, while the original is filed with the release order. The receiver's agent obtains the signature of the receiver at the destination, returning one copy to the warehouse for matching with the original Stores Requisition Voucher to confirm final delivery.

vii. At least semi-annually and quarterly if possible, conduct a physical inventory of all supplies and food aid in the warehouse to verify that the quantities on hand match with the quantities shown on the Store Cards and Stack Record Cards.

CHAPTER FIVE

5.0 PREVENTING AND CONTROLLING MYCOTOXINS CONTAMINATION FOR IMPROVED FOOD SAFETY

i	Understanding the mycotoxin contamination
ii	Understanding the effects of mycotoxins exposure and safe limits in food
iii	Understanding the risk factors for mycotoxins contamination along the production value chain
iv	Understanding prevention and control measures of mycotoxins along the production value chain

Table 5.0: CBLA Matrix/Framework

Sn	CBLA	Time in minutes	Participatory/ Activating Methods	Facilitation Materials/ Resources	Guidance Tools	Integrative Assessment Methods
a)	Understanding the mycotoxin contamination i. Defining terms related to mycotoxins contamination (*mycotoxin, aflatoxin, fumomisins, toxigenic fungi, atoxigenic fungi and food contamination*) ii. Explaining the types fungi producing mycotoxins (*Aspergillus, Fusarium, Penicillium*) iii. Identifying the crops prone to mycotoxin contamination iv. Describing the favourable condition for fungal growth	**120**	- Group discussion - Jig saw - Lecturette	- Flip chart, - Marker pens, - White/black board - Multimedia (Video, projector) - Computer	- Logbook for reflections,	- Assignment - Written test
b)	Understanding the effects of mycotoxins exposure and safe limits in food i. Knowing the mycotoxin tolerable limits ii. Describing the ways for mycotoxin exposure to human being iii. Explaining the various effects of mycotoxins contamination/exposure	**120**	- Group discussion - Lecturette - Case study	- Flip chart, - Marker pens, - White/black board - Multimedia (Video, projector) - Computer	- Logbook for reflections, - SSAF	- Assignment - Written test
c)	Understanding the risk factors, prevention and control measures of mycotoxins contamination along the production value chain i. Explaining biological control of mycotoxins (Aflasafe) ii. Explaining good agricultural practices which discourage mycotoxins contamination iii. Explaining harvesting and post-harvest practices which discourage mycotoxins contamination iv. Explaining good storage practices which discourage mycotoxins contamination	**180**	- Discussion - Brainstorming - Case study	- Multimedia (projector) - White board - Flip chart - Marker pens - Video - Crop materials with fungal growth	- Portfolio - SSAF -	- Assignments - Written test

5.1 Basic Concepts Related to Mycotoxin Contamination

Mycotoxins are toxic secondary metabolites produced by certain fungi in agricultural products that are susceptible to mould infections. Mycotoxins are colourless, odourless and tasteless and cannot be destroyed under normal cooking temperatures and during processing.

Table 5.1: Types of fungi and potential mycotoxins produced

Genera of Fungi	Mycotoxin produced
Aspergillus	Aflatoxins Ochratoxin
Fusarium	Fumonisins HT -2 toxin T-2 toxin Deoxynevalenol Zearalenone
Penicillium	Ochratoxin A

Aflatoxin

Aflatoxin is a type of mycotoxin produced by *Aspergillus flavus* and *Aspergillus parasiticus* fungi that reside in soil primarily found in warm and humid climates. There are four types of aflatoxins that are important in health and agriculture: aflatoxin B1, B2, G1 and G2. Aflatoxin B1 is highly toxic and most occurring. Aflatoxin can contaminate food crop at pre-harvest time and at post-harvest stage with high increase during storage.

Fumonisins

Fumonisins are mycotoxins mainly produced by Fusarium species; Fusarium verticillioides (syn. Fusarium moniliforme) and Fusarium proliferatum that reside in soil found in both warm and temperate regions. There are two types of fumonisins that are important in health and agriculture: fumonisin B1 and B2 with fumosin B1 as the most occurring. Fumonisins are mainly produced prior to harvest or immediately after harvest and during the early stage of the storage.

Biological control can be defined as the use of living organisms to hinder the development and depress the population of a pest.

Biological control with respect to mycotoxin control is a technique involving exclusion of toxigenic fungi by pre-infection of the plant with bio-competitive non-toxigenic (atoxigenic) fungal strains.

Toxigenic fungi are fungi capable of producing mycotoxins in agricultural produce under a certain temperature and humidity.

Atoxigenic fungi are fungi that do not produce mycotoxins

Food safety is a scientific discipline describing handling, preparation and storage of food in a ways that prevent food-borne illness.

Food Contamination is a food that are spoiled or tainted because they either contain microorganisms such as bacteria or parasites, or toxic substances that make them unfit for consumption.

5.2 Crops commonly Prone to Mycotoxin Contamination

Crops vary significantly in susceptibility to mycotoxigenic fungi infection and mycotoxin production. The major crops affected by mycotoxigenic fungi and mycotoxin contamination include:

i. **Cereals**: Maize, Sorghum, Pearl millet
ii. **Oil Seeds**: Groundnuts, Sunflower
iii. **Spices**: Chilis, Black pepper, Turmeric
iv. **Dried roots and tubers**: Cassava

Note: The crops most commonly susceptible and affected by aflatoxin in Tanzania are maize and groundnuts

5.3 Favourable conditions for fungal growth and mycotoxin production

Although different fungi are favoured by different environmental conditions, humidity above 70%, with temperature range of 10 - 40°C, and pH range of 4 to 8 is conducive for their growth and mycotoxin production (Bhat et al., 2010). Mycotoxins contaminate agricultural food products (food & feed) along the food chain.

5.4 Effects of Mycotoxins Exposure/Contamination and Their Safe Limits in Food

5.4.1 Mycotoxin safe limits in food

Most countries have developed the minimum tolerable limits for mycotoxin contaminants in foods to protect the health of the consumers. In Tanzania the limit for total aflatoxin for cereals is 5 μg/kg for AFB1 or 10 μg/kg for total aflatoxin (AFB1 + AFB1 + AFG1 + AFG2) (TZS 438: 2017). Fumonisins in cereals, grain and flours is 2000μg/kg for maize (TZS 438: 2017). With respect to Deoxynivalenol, Tanzania is using the CODEX standard which is 2000μg/kg and 1000μg/kg for unprocessed and processed cereals respectively.

5.4.2 How humans can be exposed to mycotoxin

Human beings can be exposed to mycotoxins through different ways as mentioned below:

- Human can be exposed to mycotoxins through the consumption of contaminated plant derived foods
- Consumption of animal products such as meat, eggs and milk from animals fed on mycotoxin contaminated feed
- From the breast milk if the lactating mother consumes mycotoxin contaminated food

5.4.3 Effects of mycotoxin exposure/contamination

5.4.3.1 Human health

Mycotoxins are associated with various health effects depending on the type of mycotoxin and exposure level to humans. Two types of health effects are identified; acute and chronic. **Acute effect** is observed following high levels of mycotoxin ingestion, while **chronic effect** occurs due to high frequency intake of low level of mycotoxins over a long period of time.

Acute and chronic effects of aflatoxin

The health condition resulting from consuming aflatoxins is referred to as aflatoxicosis. Acute aflatoxicosis is a result of direct liver damage due to consumption of high level of aflatoxins. Acute aflatoxicosis has occurred in different countries like in Kenya (Shephard 2008 a, b) where from 317 affected; 125 people died and in Tanzania where from 68 affected; 20 people died in 2016 (Kamala et al., 2018). Clinical symptoms in human include: Abdominal pain, vomiting, pulmonary oedema, liver necrosis and jaundice.

Chronic aflatoxicosis has been extensively associated with liver cancer and also with nutritional and immunological effects (IARC, 2002). In humans, aflatoxins have been shown to retard both in utero and postnatal growth; and higher levels of Aflatoxin-albumin in maternal blood are associated with lower weight and height gain. Strong correlation has also been observed between occurrence of aflatoxins and incidences of kwashiorkor in infants. Growth impairment is also linked to aflatoxin exposure. Aflatoxins are classified by the International Agency for Research on Cancer (IARC) in group 1: ‘‘carcinogenic to humans”.

Acute and chronic health effects of fumonisins

It is documented and reported that the main target organs of fumonisin are liver and kidney. However, the toxin affects liver in all species but not kidney. Acute toxicity of fumonisins has been reported in India in 1995 where people presented with abdominal pain and diarrhoea after consuming damaged mouldy sorghum and maize which were confirmed to contain high levels of FB1.

Chronic exposure to fumonisins has been linked to carcinogenic effects in particular the high incidences of oesophageal cancer in the Transkei region of South Africa, Central China and Iran. The

exposure also is associated with impaired growth in children and neural tube defects. Furthermore, the combined effects of fumonisins and other mycotoxins indicated that fumonisins might have synergistic effects with other mycotoxins such as aflatoxins. FB1 are classified by the International Agency for Research on Cancer (IARC) in group 2B: "possibly carcinogenic to humans".

5.4.3.2 Livestock Industry

Mycotoxins contamination of crop and the ensuing consumption of contaminated feed ingredients by animals is an inevitable part of animal production system. Mycotoxins produce wide range of injurious effects in animals. The effect may be acute or chronic. Generally, in cattle, calves are more susceptible than older ones. E.g. aflatoxins exert carcinogenic, teratogenic, hepatotoxic and mutagenic effects and also suppress the immune system of livestock. It may cause a drop in milk production, reduced egg weight and anaemia in livestock. Furthermore, it is also associated with reduced feed consumption and overall retarded growth and development in livestock.

5.4.3.3 Agriculture, trade and economic impact of mycotoxins

Mycotoxin contamination leads to rejection of affected crops in the market both locally and internationally leading to lack of markets. This is likely to result in price reduction below the production cost rendering crop production uneconomical. Production is therefore reduced because of discouragement. Revenues at farm and national level are reduced leading to reduced agricultural production. Mycotoxins therefore negatively affect agriculture, trade and the economy in general.

The economic impact of mycotoxins includes loss of human and animal life, increased health care and veterinary care costs, it can lead into low productivity due to weak labour force, reduced livestock production, disposal of contaminated foods (food insecurity) and feeds, and investment in research and applications to reduce severity of the mycotoxin problem.

5.5 Risks, Prevention and Control Measures of Mycotoxins along the Value Chain

a) Planting and crop rotation

i. Consider developing and maintaining an appropriate crop rotation/sequence schedule to avoid planting the same crop in the same field for two consecutive seasons. This can help to reduce the inoculum in the field which may originate from debris remaining after harvest that harbours toxigenic fungal spores. Crops of low susceptibility to toxigenic fungi such as legumes can be used in rotation to reduce the inoculation in the field.

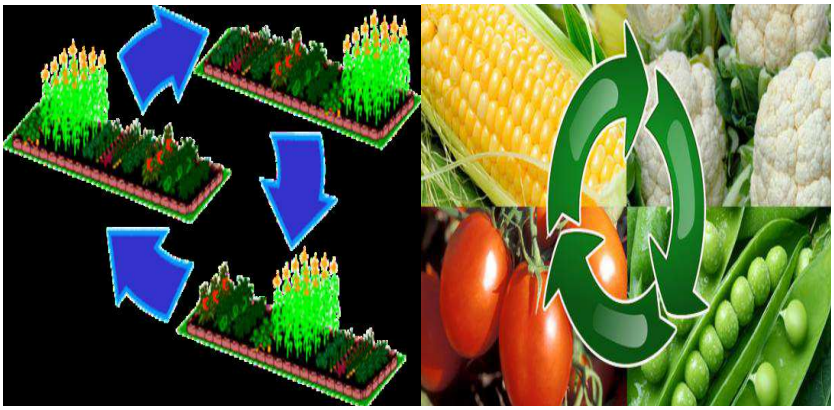


Figure 5.1: Models of crop rotation

b) Tillage and preparation for seeding (planting)

i. Use certified seeds and prepare the seed bed for each new crop by ploughing under or by destroying or removing old seed heads, stalks, and other debris that may have served, or may potentially serve as substrates for the growth of mycotoxin producing fungi.

ii. Utilise the results of soil tests to determine which fertilizer to use for optimum nutrient availability and soil pH.

iii. Plant crop varieties recommended for specific location.

iv. Ensure timely planting at the onset of rains to avoid drought stress during the period of seed development and maturation.

v. Ensure appropriate density of planting by maintaining the recommended row and intra-plant spacing for the species/varieties grown.

c) Pre-harvesting

i. Minimise insect damage and fungal infection in the vicinity of the crop by proper use of approved pesticides and other appropriate practices within an integrated pest management programme.

ii. Control weeds in the crop by using mechanical methods, registered herbicides or other safe and suitable weed eradication practices utilizing an integrated pest management programme.

iii. Minimise mechanical damage to plants during cultivation, irrigation and pest management practices.

iv. Minimise lodging of plants to prevent contact of the aerial parts of the plants with soil, particularly at the flowering stage of the crop.

v. Ensure adequate supply of water if irrigation is used in reducing plant stress in some growing situations.

vi. Apply biocontrol method. For example, use of **Aflasafe**

Aflasafe is a mixture of four atoxigenic strains of *Aspergillus flavus* of Tanzania origin. Atoxigenic strains in Aflasafe compete with toxigenic strains that producing aflatoxin and in so limiting the amount of aflatoxin contamination in crops.

Aflasafe is used two weeks before tasseling in maize and two weeks before flowering in groundnuts. Application is by broadcasting at the rate of 4 kgs per acre every season. It is important to use Aflasafe after fertilizer application and weeding have been done. Aflasafe should not be buried in the soil for spores to freely move around the field after sporulation (IITA 2018).

Figure 5.2: A farmer hand-broadcasting Aflasafe in a maize field

d) Harvesting

i. Timely harvesting at full maturity. Delayed harvest of grain already infected by toxigenic fungi species may cause an increase in the mycotoxin content of the crop.

ii. Use clean containers during transportation to avoid spreading contamination.

iii. Avoid mechanical damage to the grain and avoid contact with soil during the harvesting operation.

iv. Destroy infected/affected crop residues to avoid further spread to the next season.

v. Ensure the correct moisture content is attained uniformly after harvesting before storage.

vi. Avoid harvesting grain with high moisture content due to precipitation or morning dew or during late afternoon as it takes a longer time to dry.

vii. When pre-harvest monitoring or surveying of grain shows a field as having a higher fungal infection rate, harvest and store grain from such field(s) separately from those fields with a lower infection rate.

viii. Transit time for movement from field to drying facility should be minimized.

ix. When necessary if there is no rain, it is recommended that the trucks and containers be opened, to increase aeration and minimise the condensation effects.

Figure 5.3: Produce should be arranged neatly on wooden pallets when transporting

Figure 5.4: Transporting without a waterproof cover in humid or rainy conditions allows wetting of the produce. Fungal infection and aflatoxin contamination will probably occur.

e) Drying and cleaning before storage

i. Avoid piling, heaping, or bin storage of high-moisture, freshly harvested commodities for more than a few hours prior to drying or threshing to lessen the risk of fungal growth. If it is not possible to dry the commodities immediately, aerate them by forced air circulation.

ii. When necessary pre-cleaning before drying can be carried out to remove large amounts of straw or other plant material that can carry mould or mould spores.

iii. Winnowing and sorting methods can be utilised to clean the grain. If cleaning equipment is available, it is advantageous to mechanically clean grain to remove foreign material, seeds of other plant species, and crop residues prior to transfer to storage structures. However, it is important that the grain is not damaged during the procedure.

iv. It is important to ensure that moisture levels in harvested grains are low enough to permit safe storage for even relatively short periods of time ranging from a few days to a few months.

Table 5.2: Values of grain moisture content in relation to water activities at 25 ºC

Cereal/grain	Moisture content (%) at various water activity			
	0.60	0.65	0.7	0.75
Rice	13.2	13.8	14.2	15.0
Oat	11.2	12.2	13.0	14.0
Rye	12.2	12.8	13.6	14.6
Barley	12.2	13.0	14.0	15.0
Maize	12.8	13.4	14.2	15.2
Sorghum	12.0	13.0	13.8	14.8
Wheat	13.0	13.6	14.6	15.8

v. A maximum level of 13.5% moisture is generally considered to be low enough to prevent further growth of pre-harvest toxigenic fungi and germination of spores of fungi that typically infect grain and produce mycotoxins during storage, such as *Aspergillus* and *Penicillium*.

Different techniques used for moisture content determination

A: Moisture Meter

B: Salt and

C: Dry Card

Figure 5.5: Tools for measuring moisture content of cereals

vi. Freshly harvested cereals should be dried immediately in such a manner that damage to the grain is minimized and moisture levels are lower than those needed for fungal growth during storage.

vii. If it is not possible to dry the commodities immediately, aerate them by forced air circulation and keep the period before drying as short as possible.

viii. Grains should not be excessively dried or subjected to excessively high drying temperatures in order to preserve nutritional quality and suitability for milling or other processing.

ix. The use of good drying practices is essential to avoid contaminants generated by the process.

Figure 5.6: Dry maize in elevated platforms

Figure 5.7: Drying maize on tarpaulin

x. If mechanical means of drying are not available, sun and open air drying should be done on clean surfaces to the extent possible. Grains should be protected from rain, dew, soil, pests, bird droppings and other sources of contamination during this process. For more even and faster drying, mix or stir grains frequently in thin layers.

xi. After drying, cereal grain should be cleaned to remove damaged, spoiled and immature kernels and other foreign matter.

f) Storage after drying and cleaning

i. It is important that bins, silos, sheds and other buildings intended for grain storage are dry, well-vented structures that provide protection from rain, ground water, moisture condensation, and the entry of rodents, birds and insects that cannot only contaminate grain, but damage grain kernels to render them more susceptible to mould infection.

ii. Storage structures should be designed to minimise wide fluctuations in the temperature of the stored grain.

Figure 5.8: Metal silo

Figure 5.9: Hermetic bags

iii. The use of hermetic storage technology is recommended because it does not require pesticides. Care should be taken when using hermetic bags to avoid pricking them as this will compromise the passage of air.

iv. Storage facilities should be cleaned prior to receiving grain to remove dust, fungal spores, grain, crop residues, animal and insect excreta, soil, insects, foreign material such as stones, metal and broken glass, and other source of contamination.

v. For bagged commodities, ensure that bags are clean, dry and stacked on pallets or incorporate a water impermeable layer between the bags and the floor. The bags should facilitate aeration and be made of nontoxic food-grade materials that do not attract insects or rodents and are sufficiently strong to resist storage for longer periods.

Figure 5.10: Well stored crop bags

vi. Determine moisture content of the lot, and if necessary, dry the crop to the moisture content recommended for storage.

vii. Ongoing monitoring of the condition of stored grain is essential to ensure the grain is kept at acceptable temperature and moisture levels and substantially free of rodents and stored product pests such as grain beetles, weevils and mites.

viii. Use good housekeeping procedures to minimise the levels of rodent pests, insects and fungi in storage facilities. This may include the use of suitable, registered insecticides and fungicides or appropriate alternative methods within an integrated pest management programme. Care should be taken to select and use only those pest control products that will not create a safety concern based on the intended end use of the grains and the maximum levels of pesticide residue dictated by regulation or buyer specifications.

ix. Document the harvesting, drying, cleaning and storage procedures implemented each season by making notes of measurements (e.g. temperature, moisture, and humidity) and any deviation or changes from traditional practices. This information may be very useful for explaining the cause(s) of fungal growth and mycotoxin formation during the year and help to avoid similar occurrences in the future.

g) Transport from storage

i. Transport containers, vehicles such as trucks and railway cars and vessels (boats and ships) should be dry and free of old grain, grain dust, visible fungal growth, musty odour, insects and any contaminated material that could contribute to mycotoxin levels in lots and cargoes of grain.

ii. The use of registered fumigants or insecticides may be useful. At unloading, the transport container should be emptied of all cargo and cleaned as appropriate.

iii. Shipments of grain should be protected from additional moisture by using covered or airtight containers or tarpaulins.

iv. Minimise temperature fluctuations and measures that may cause condensation to form on the grain, which could lead to local moisture build-up and consequent fungal growth and mycotoxin formation.

v. Avoid insect, bird and rodent infestation during transport by using insect- and rodent-proof containers or insect and rodent repellent chemical treatments if they are approved for the intended end use of the grain.

h) Processing and cleaning after storage

i. Sorting and cleaning are effective processes to remove contaminated grains and reduce mycotoxin content in cereals. Visibly mould infected and/or damaged kernels should be discarded in order to prevent their entry into the food and livestock feed supply chains.

Figure 5.11: Sorting maize before milling

ii. In the case of aflatoxin, brushing, scouring and peeling to remove hulls and bran layers of the grain can significantly reduce mycotoxin content in milling fractions derived from the endosperm (i.e. flour) as the outer parts of the kernel of most cereal grains typically contain higher mycotoxin levels or adhering contaminated dust.

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APPENDICES

Appendix 1: Post-harvest management of sesame

Introduction

Sesame (*Sesamum indicum* L.) is one of the world's oldest spice and oilseed crop grown mainly for its seeds that contain approximately 50% oil and 25% protein. Sesame has one of the highest oil contents of any seed. With a rich nutty flavour, it is a common ingredient in cuisines across the world. Sesame is considered to have both nutritional and medicinal values. The seeds are used either decorticated or whole in sweets such as sesame bars and halva, in baked products, or milled to get high grade edible oil or tahini, an oily paste. Africa is naturally endowed with favourable climatic and soil requirements that can support sesame production.

Maturity and harvesting

The sesame development is sequenced into several development stages, starting from the day after planting (DAP) to the harvest stage. Harvest commences as soon as the leaves fall away. It is important to note that this is the most critical period as an inexperienced farmer can lose most seeds through shattering. Sesame seeds are protected by a capsule which only bursts when the seeds are completely ripe. At maturity stage, plants continue yellowing, lose the final leaves, and lose moisture. The full maturity stage ends when 90% of all plants have seeds mature to the top of the plant. The ripening time tends to vary. In order to know that sesame crop is ready for harvesting you must see the following signs;

i. Leaves start to fall down; this also can be caused by diseases; hence, if you see this sign count the days from sowing to present stage (ripening); short duration varieties grow in 90-105 days; medium duration varieties in 110-115 days.
ii. The plants tend to turn from green to yellowish.
iii. The down capsule starts to burst.

The onset of these sings signifies the maturity stage of the sesame and hence signalling that the crop is ready for harvesting. At harvesting time, it is recommended to use a sharp knife to cut the stem and bind it to 10-15 stems for drying, make sure not to bind too tightly to allow air to pass through the bundle of sesame trees. The plants must be placed in an upright position to continue drying.

Maturity indices of sesame seeds: Indicated by yellowing and falling of 90% of leaves.

Post-harvest management

Post-harvest management is the group of activities that commences after harvesting and aims at reducing losses, extending shelf life, maintaining the quality of the harvest and/or adding value of the crop. It includes the following activities;

a) Cleaning/winnowing-removal of foreign matters

The process of removing seeds from the capsule of dried sesame plants is done after two weeks of drying using a stick. This activity is usually done from 10 am when there is sun, to allow the seeds to be removed easily. It also makes it easier to place the mat, tarpaulin or bed sheet down in order to prevent sesame seeds to get contaminated with soil. This is one of the important aspects of the quality control to ensure good market price of the product. Winnowing process will be done by using winnowing basket to remove all dust, sands and any other foreign matters.

Seed removal from capsule is usually associated with cleaning/winnowing to removal unwanted foreign matters

b) Grading/standards

Grading and marketing of agricultural produce as per accepted quality standard help farmers, marketing functionaries, processors, traders and consumers in efficient marketing. Sesame seeds vary in colour. The two main colours are white and black. Hence, during grading, if the intention is white seeds, then all black seeds must be removed in order to get good price in the market. The lighter coloured seeds are considered to be of higher quality compared to dark ones. Generally, grading helps in meeting the set standards set in the market and hence;

i. It enables the farmer to get a higher price for the produce.
ii. It facilitates competitive marketing.
iii. It widens the marketing process as buying and selling can take place between two parties at distant places, by quoting standard grades.
iv. It reduces the cost of marketing and minimizes storage losses.
v. It facilitates maintaining quality of the produce.
vi. It helps the consumers getting standard quality of produce at reasonable prices, and
vii. It facilitates the futures trading and thus helps in price stabilization.

c) *Packaging*

Proper packaging provides physical protection against contamination, damage or handling losses during transportation of sesame seed. Packaging also plays an important role in marketing of produce. Since the produce is handled many times between production and consumption, appropriate packaging is necessary for protection of produce quality. More care is to be taken in packaging of sesame seeds meant for export by selecting suitable packaging materials.

(a) **(b)** **(c)**

Typical examples of bags useful for long term storage of sesame seeds, (a) Jute bag, (b) Multi-wall paper bag and (c) High density polyethylene (HDPE)

d) Storage

Storage protects the seeds from quality deterioration and helps in stabilization of prices by balancing demand and supply. Furthermore, storage provides protection against weather, moisture, insects, micro-organisms, rats, birds and any type of infestation and contamination. It is recommended that only well-dried sesame seeds should be packaged in bags for storage. If not properly dried, sesame seeds are likely to go rancid due to hydrolytic breakdown of their natural oils, developing rancid odour and nasty taste. The bags of sesame seeds should be stacked on pallets not exceeding 10-12 bags in height. This will allow proper aeration and easy fumigation. The bags should be fumigated with methyl bromide (MBr) or other suitable recommended fumigant once every 3-4 months. This practice can safely keep the sesame seeds for about 12 months. It should be noted that, fumigation with MBr is only recommended for export stocks, while the Montreal protocol restricts its use for domestic fumigation. Even in cases where the stock is for export, and where the buyer allows MBr fumigation, the residue levels differ from country to country. The best way to keep sesame seeds safe and in good quality for long term storage is through practicing the proper hygiene and normal principles of food safety.

Well-managed warehouses for safe storage of sesame seeds

e) Transportation

Transport for sesame is frequently done by road trucks, rail trucks and by ships, especially for export to oversee markets. Steps useful in transport of packed sesame seeds include the following;

i. Bulk grains and bags are prepared immediately after threshing. Drying for about 2-3 more days under direct sunlight is necessary to prevent spoilage prior to transport to distant/ oversea markets.
ii. Stack bags on pallets to improve aeration.
iii. Tag bags and transport bags to designated collection centres.
iv. Weigh bags in designated collection centres and record weight in ledgers.
v. Transport weighed grains to larger collection centres, distant markets or oil mills.

Appendix 2: Post-harvest management of sunflower seeds

Introduction

Sunflower is one of Tanzania's most important cash crops grown mostly within the central regions of Tanzania. It is one of the major sources of vegetable oil in the country and in the globe at large; it represents one of the key sub-sectors of agriculture in Tanzania. Sunflower is a drought tolerant crop, which can survive in areas with low to medium rainfall. The crop is less susceptible to diseases and cheaper to cultivate compared to other oilseed crops like sesame as well as food crops like sorghum and maize. Accordingly, sunflower is grown in many parts of the country by small-scale farmers.

Harvest maturity

Physiological maturity signifies when the maximum seed weight has been reached. The crop can then be harvested at any time, however sufficient drying down needs to occur to reach a moisture content suitable for storage or delivery. Harvesting should commence as soon as 80% of the sunflower heads are brown to minimise losses caused by birds, lodging and shattering. The leaves turn yellowish during harvesting maturity. Sunflower is generally mature long before it is dry enough for combining. The sunflower plant is physiologically mature when the back of the head has turned from green to yellow and the bracts are turning brown, about 30 to 45 days after bloom, and seed moisture is about 35 %. The total growing period (from seeding to harvesting) for sunflower ranges from 125 to 130 days.

Harvesting methods

Harvesting is done either manually or mechanically. Manual harvesting is practiced by cutting the crop with a sickle or knife. Commercially available sunflower headers are useful in decreasing loss of seed as the crop is directly combined. The combines are used to perform several operations such as cutting the crop, separating the grain from the straw, cleaning the grain from chaff and transporting grains to the storage tank. Harvesting with a combine harvester will save more time than manual harvesting. Harvesting sunflower at higher moisture contents normally results in higher yields and less field loss. Early harvest also reduces exposure to late-season wet and cold weather. Frequently, mechanical drying is required so harvesting can be completed.

Post-harvest management

Proper post-harvest management is required. Post-harvest losses usually occur at different stages such as harvesting, threshing, winnowing, transportation, packaging, storage and processing**.** The preventive measures that can be followed as principles to reduce post-harvest losses include:

i. Harvest timely/or at right maturity to reduce losses,
ii. Adopt proper method of harvesting,
iii. Adopt modern mechanical methods to avoid the losses in threshing and winnowing,
iv. Use improved techniques of processing,
v. Adopt the proper grading to get better price,
vi. Use good packaging materials for storage and transportation
vii. Use proper techniques in storage,
viii. Dry sunflower seeds adequately (moisture content < 9.5%) during storage,
ix. Adopt proper pest control measures during storage, and
x. Adopt timely and proper handling while loading and unloading.

a) Drying

Drying of seeds is the first step in sunflower seed processing. The moisture content of freshly harvested sunflower seeds may be as high as 20%. To ensure safe storage, the seeds must be dried to less than 10% moisture. Sunflower seed is decorticated before the oil is extracted to ensure that the cake is a nutritious animal feed.

b) Sorting and grading

After harvesting all foreign materials, weed seeds, undesired seeds, stones and leaves should be sorted out from the desired seeds. Seeds should be sorted small according to their colours and size in order to meet the market standards. Classes or grades of sunflower seeds can be set based on a number of factors such as oil content, colour and size as demanded by the targeted market. Tanzania sunflower sector can deploy the grading system used in other countries to meet the market standards to export seeds and sunflower oil. For instance, the South Africa (RSA) grading system of the sunflower seeds is based on the presence or absence of the following attributes;

i. Musty, sour, khaki-weed or other undesirable smell
ii. Any substance that renders the sunflower seeds unsuitable for human or animal consumption or for processing into or utilization as food or feed
iii. Contains not more than 10 % moisture
iv. Contains not more than 5 noxious seeds per 400 g, of which no more than one may be of Crotalaria species and of which none may be of *Ricinuscommunis*
v. Free of stones, glass, metal, coal or dung; fFree of insects

vi. Maximum permissible deviation (exceeding or not exceeding)

Sunflower seeds of different quality and grades

c) Packaging

Sunflower seed shall be packed in suitable packages which shall be clean, sound, free from insects and fungal infestation. The packing material shall be of food grade quality. Sunflower seed shall be packed in containers which will safeguard the hygienic, nutritional, technological and organoleptic qualities of the products. The containers, including packaging material, shall be made of substances which are safe and suitable for their intended use. They shall not impart any toxic substance or undesirable odour or flavour to the product.

d) Storage and management of storage facilities

For safe storage of oilseeds, proper drying to the correct moisture level is essential and the moisture content must be lowered to a level that prevents the growth of moulds, generally in the range of 5 - 15 %. Adequate drying is particularly important as sunflower seeds are susceptible to the growth of moulds that produce poisons that are linked to the development of cancer. For instance, Aflatoxin, if present, contaminates both the oil and more importantly the oilcake remaining after extraction. There have been several high-profile instances of deaths occurring in poultry fed with Aflatoxin contaminated feed. This highlights the need for routine inspection of oilseeds for any signs of moulds growth during storage. Rejection of any lot or consignment with moulds growth is recommended. In addition, good storage practices require that storage facilities such as silos, storerooms or warehouses are well ventilated and well equipped with protection against rodents and insects. Adequately dried oilseeds should be packaged into bags and stalked on pallets. Furthermore, during long term storage routine store inspections should be carried out, checking for insects, rodents and the pickup of moisture by crops.

For medium and large-scale storage, aeration is essential. Aeration may be accomplished with floor-mounted dusts or portable aerators. Sunflower should be rotated between bins when aeration is not available. An air space should be left in the top of the bin to facilitate checking the condition of the stored seeds. Sunflower can be stored more than one season under proper conditions (dry, clean, aerated, and in tight bins), however, processors of non-oilseed sunflower for human consumption prefer not to use seed that has been stored more than one season.

e) *Transport*

The most frequent mode of transport for sunflower grain is by road trucks, rail trucks and by ships, especially for export to oversee markets. Farmers/ sellers need to ensure transport means that will ensure keeping of quality until it reaches the consumer;

Quality control of oilseeds

Sanitary and phyto-sanitary requirements

Food safety has become a serious societal issue because of pathogens and food contamination. Getting a safe produce begins with the production and handling practices on the farm. A produce grown and sold with little biological contamination is less likely to result in health hazards caused by poor handling during later preparation stages. Farmers/producers have the critical job of minimizing product contamination by learning about potential sources of contamination and by using Good Agricultural Practices (GAPs), e.g., a set of recommendations that can help improve the quality and safety of the produce grown.

The sanitary and phyto-sanitary (SPS) measures are an integral part of any export trade agreement. The SPS agreement applies to all sanitary and phyto-sanitary measures, which may directly or indirectly affect international trade. Sanitary measures relate to human and animal health while phyto-sanitary measures are related to plant health. SPS measures are applied in five situations for the protection of human, animal or plant health. These include the following are:

i. Risks arising from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms.
ii. Potential risks coming from additives, contaminants, toning or disease-causing organisms in foods, beverages or feedstuffs.
iii. Risks arising from diseases carried by animals, plants or products thereof or from the entry, establishment or spread of pests.
iv. Prevention or limitation of damage caused by the entry, establishment or spread of pests.
v. Prevention of aflatoxin contamination that can occur in the field, before harvest, during harvesting and post-harvest handling processes, e.g. field sun-drying, storage, and

transportation of product. (Note: the soil in the field is known as excellent storage medium for aflatoxin-producing fungi, e.g. Aspergillus species). Postharvest aflatoxin contamination occurs if the seeds gets moist and/or damaged, which can occur at harvest or later.

Methods to control aflatoxin contamination

i. Avoid mechanical damage to pods or seeds during weeding, harvesting and storage;
ii. Harvest seeds as soon as they are mature;
iii. Dry properly (until moisture content is reduced to about 10 %); this will help avoid *Aspergillus* infestation and consequent aflatoxin contamination. Normally this can be achieved by sun-drying of pods, and avoiding seed exposure to rains;
iv. Store dry seeds under moisture-free conditions. Moist seeds are prone to fungal diseases, as mould spores are present in all crops.

General SPS standards commonly applied by Governments as they affect imports include

i. Import ban (total/partial) when there is a significant risk about a hazard.
ii. Technical specifications (process standards/technical standards) are the most widely applied measures and permit import subject to compliance with pre-determined specifications.
iii. Information requirements (labelling requirements/control on voluntary claims) permit imports provided they are appropriately labelled.

Appendix 3: Post-harvest handling of cereals

Introduction

Each type of cereal requires a specific post-harvest treatment; however, there are certain general principles that apply to most of them. Cereals undergo a number of processing stages between harvest and consumption. This chain of processes is often referred to as the total post-harvest system. The post-harvest system can be split into three distinct areas.

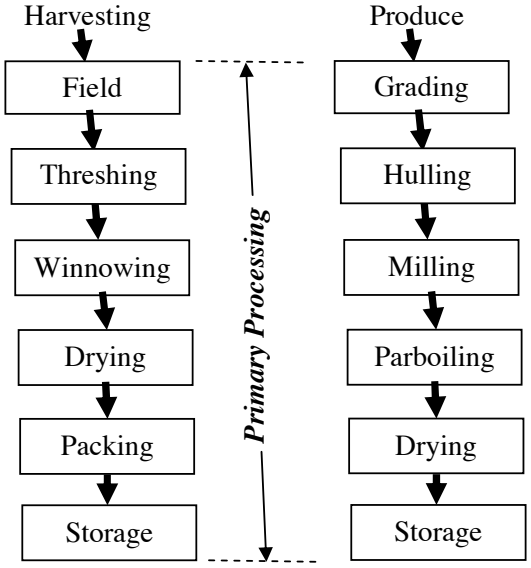
i. The first is the preparation of harvested grain for storage.

ii. The second, which is referred to as primary processing, involves further treatment of the grain to clean it, remove the husk or reduce the size. The products from primary processing are still not consumable.

   - **Primary** processing involves several different processes, designed to clean, sort and remove the inedible fractions from the grains. Primary processing of cereals includes cleaning, grading, hulling, milling, pounding, grinding, tempering, parboiling, soaking, drying, sieving.

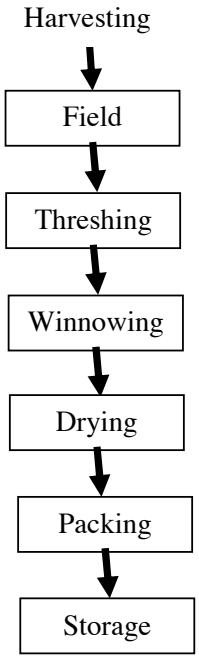
iii. The third stage (secondary processing) transforms the grains into edible products.

   - **Secondary** processing of cereals (or 'adding value' to cereals) is the utilisation of the primary products (whole grains, flakes or flour) to make more interesting products and add variety to the diet. Secondary processing of cereals includes the following processes: fermentation, baking, puffing, flaking, frying and extrusion.



Projects and small businesses may involve only one or several of the activities in the total chain, from the growing of crops through to the production of edible products. Some small businesses are set up to clean and package wholegrains. These businesses can be successful as there is very little need for equipment. However, as with all businesses, there must be a clear demand for the product.

Post-harvest treatment for storage of cereals



i) Harvesting

- There is an optimum time for harvesting cereals, depending on the maturity of the crop and the climatic conditions. This has a significant effect on the quality of the grain during storage.
- Harvesting often begins before the grain is ripe and continues until mould and insect damage are prevalent. Grain not fully ripened contains a higher proportion of moisture and will deteriorate more quickly than mature grains because the enzyme systems are still active.
- If the grain remains in the field after maturing, it may spoil through wetting caused by morning dew and rain showers. There is also an increased risk of insect damage.
- Cereals are traditionally harvested manually. There are three main types of harvesting equipment for the small-scale producer: manual, animal powered and engine powered.
- A range of mechanised harvesting equipment suitable for the small-scale farmer has been developed. Some of it is more efficient and cost effective than others.
- Harvested crops are left in the field for a few days to dry before further processing.

ii) **Threshing**

- Threshing is the removal of grains from the rest of the plant. It involves three different operations: Separating the grain from the panicle; sorting the grain from the straw; winnowing the chaff from the grain.
- Separation of the grain from the panicle is the most energy-demanding process. It is the first process to have been mechanised. Sorting the grain from the straw is relatively easy but is difficult to mechanise. Winnowing is relatively easy, both by hand and by machine.
- Most manual threshing methods use an implement to separate the grain from the ears and straw. The simplest method is a stick or hinged flail that is used to beat the crop while it is spread on the floor. A range of engine powered threshers are available. Some farmers also use animals for threshing.

iii) Winnowing

- Winnowing is the separation of the grains from the chaff or straw. It is traditionally carried out by lifting and tossing the threshed material so that the lighter chaff and straw get blown to one side, while the heavier seeds fall down vertically.
- Hand-held winnowing baskets are used to shake the seeds to separate out the dirt and chaff. They are very effective, but slow.
- There are winnowing machines that use a fan to create artificial wind to speed up winnowing. Some machines contain sieves and screens that at the same time grade the grains.

iv) Drying

- Prior to storage or further processing, cereal grains need to be dried. The most cost-effective method is to spread it out in the sun to dry. In humid climates it may be necessary to use an artificial dryer.
- Simple grain dryers can be made from a large rectangular box or tray with a perforated base. The grain is spread over the base of the box and hot air is blown up through a lower chamber by a fan. The fan can be powered by diesel or electricity and the heat supplied by kerosene, electricity, and gas or burning biomass. Cereal grains should be dried to 10-15% moisture before storage.

v) Storage

- Dried grains are stored in bulk until required for processing. The grains should be inspected regularly for signs of spoilage and the moisture content tested. If the grain has picked up moisture it should be re-dried. Grains are often protected with insecticides and must be stored in rodent-proof containers.

Appendix 4: Good storage practices for grains

Good storage practice means, grain is to remain in good condition from harvest to the time that it is consumed or sold; the farmer must follow the four pillars of good storage practice. This means:

i. Ensuring that the crop going into the store is in good condition;
ii. Keeping the store in good condition;
iii. Practicing good store hygiene; and
iv. Maintaining the condition of crop and store throughout the storage season.

i. Ensuring that the crop going into store is in good condition

- Good quality whole grain is less likely to suffer insect attack than poor quality damaged one.
- The grain should be checked after maturity while the crop is still standing in the field but immediately before harvest. Grain that shows signs of infestation or damage should be separated out before harvest and either discarded, reserved for animal feed or, depending on the type and extent of damage, kept for immediate consumption.
- The grain should be thoroughly cleaned and any damaged grain removed. Careful winnowing will remove many live adult insects. Straw, chaff, weed seeds, stones and dirt must be removed. These materials will hold water and their removal will allow grain to dry faster. Any rubbish should be burnt.
- The grain should be well dried. Good drying is essential. Damp grain will become mouldy. Insects are less likely to attack well dried grain. If the crop is to be dried in the field, it should not be heaped directly on the ground in order to prevent moisture being taken up. Similarly, when grain is dried at the homestead it must be kept off the soil.
- Threshed grain can be dried on polythene sheeting, grass matting or sacks placed on the ground in the sun. Unthreshed crops, (cobs, heads and pods) can be dried in the same way although it is better to dry them on platforms or frames or in cribs. Solar dryers can be used for grain if these are available in the village. Sun drying will help get rid of adult insects in the grain. Weevils will walk away from grain spread in the sun or will be killed if the grain gets hot quickly. Sun drying will not kill all immature stages, like larvae, which live inside the grains. If adults have been found, it may be necessary to treat the grain with an insecticide, which will kill the immature stages once they mature and emerge from the grain as adults.
- The crop should be carefully handled once it has dried to ensure that grain remains intact. This will limit problems from secondary insect pests and moulds.

- In some places, farmers shell or thresh grain by placing it in a sack and beating it with sticks. Although this may be quick, the process does result in a high proportion of broken grains that will be susceptible to insect attack and mould infection.
- Maize is often shelled by hand. This produces better quality grain but is a very slow process. Quicker and effective shelling can be achieved using a variety of handheld gadgets or pedal-operated machines. For these to work effectively, the grain must be sufficiently dry for safe storage; wet grain is difficult to shell. Although these devices make shelling more efficient, they are relatively scarce in farming communities.

ii. Keeping the store in good condition

- A good store will keep the grain dry and cool. It should provide protection against rodents, birds and browsing domestic animals and poultry. It should be theft proof.
- Stores should be sited in areas that are not prone to flooding; the soil should allow water to drain away readily. They should not be placed where high winds might damage the structure or near trees, which might provide access points from which rodents can jump onto the store roof or platform.
- The store should have a roof to keep rain off the structure and to provide shade during the heat of the day. Without shade, the changes in temperature inside the store between day and night may be so great that as the store cools at night condensation occurs and wets the grain, which in turn may lead to the development of moulds. This is particularly important for metal grain bins.
- To prevent groundwater soaking into the store, the structure must be raised off the ground. Mud silos and bins need only be supported on rocks or stones to create a small air gap. "Unplastered" structures should be raised at least 1 m above the ground to prevent rodent entry; they should be fitted with rat guards.
- Most types of stores, apart from sealed mud silos, polyethylene and metal tanks, do not provide protection against insect entry; therefore they must be treated with insecticide. The commonly available storage insecticides will also protect woven baskets against damage by the bamboo beetle (Dinoderus) and other wood-boring beetles.
- The store must be kept in good repair to stop the roof leaking or the sides collapsing. A door should be fitted in the wall of the structure for access to the grain. A door eliminates the need to keep removing the store roof to gain access.
- At the beginning of the new storage season the empty store must be cleaned. Residues of old grain and other rubbish must be removed and burnt. The roof and walls must be inspected

and repaired where necessary; a thatched roof may need only some small repairs, but most will need to be replaced every year.

iii. Practising good store hygiene

- This means keeping everything as clean as is practically possible.
- The store surroundings should be tidied so that there is no vegetation or rubbish to hinder inspection or to provide breeding grounds for insects and rodents. Clearing the ground around the store will make it easy to spot termite trails. Livestock should be kept away from the store; they should not be allowed to browse or sleep under the store; droppings should be cleared up as they attract rodents.
- Whenever the storage containers are empty, they should be cleaned. Second-hand sacks should be dipped into boiling water to kill any insects and then dried in the sun. Grain residues should be removed from sacks by turning them inside out and thoroughly brushing them. Holes should be stitched.
- Grass should be burnt inside solid walled bins and mud plastered baskets to kill off insects and mould spores. It is good practice to sprinkle the inside walls and floor of the structure with insecticide to kill any remaining insect pests. Old grain should be stored separately from the new crop and it should be used first.

iv. Maintaining the condition of the crop and the store throughout the storage season

- Pests can attack the store at any time; therefore, it is important to inspect the store and crop regularly. The earlier a problem is spotted, the sooner action can be taken to control it so that less damage is done. Early action will prevent damage becoming severe.
- If insect pests are a regular occurrence the grain should be treated with insecticide as soon as possible. Maize cobs can be sprayed with insecticides, but it is more effective to shell the cobs and mix the grain with insecticide dust. It is particularly important to shell and treat pulses, especially beans and cowpeas, which become infested very quickly.
- Store inspections should start as soon as the grain is put in store and then conducted routinely at weekly intervals. This is because insects may be brought in with the crop, which may have become infested in the field during harvesting or drying, or the store itself may have harboured an infestation from the previous season.
- Even if the crop is insect free at the start of storage, regular inspection is necessary to spot insects that might fly in from a neighbour's store, trees and vegetation, or from grain purchased from the market. It is important to remember that maize insect pests will also attack sorghum, millet, dried cassava, dried sweet potatoes, rice and wheat.

- During inspection, insect adults and signs of their presence should be looked for, such as holes in the grain, moth webbing, and large amounts of dust in the grain, on maize cobs, on the outside surfaces of bags and under the store.
- If infestations are seen, action must be taken as soon as possible. This usually means treating the grain with insecticide, but it may be possible to sell untreated grain for immediate use if the damage is light.
- *For maize cobs* – cobs should be shelled, and the grain treated with an approved insecticide dust. It is not sufficient to treat the cobs because by this time the infestation will be present inside the grain and immune from a spray treatment.
- As cobs are taken from the store, those that are heavily damaged should be separated for immediate use or disposal. Unwanted cobs and damaged grain that cannot be used for brewing or livestock feed should be burnt.
- Infested pulses in pods and heads of cereals should likewise be threshed and the grain treated with insecticide unless it is to be consumed quickly.
- For shelled grain and pulses stored in bags, baskets or bins – the grain should be removed from store and adult insects removed by sun drying or sieving and winnowing the grain. Dust and insects are then swept up and burnt. If the grain is not going to be used immediately, it should be mixed with an approved insecticide before storing again. The bags, baskets or bins should be cleaned before putting the grain back.
- Signs of mould damage also need to be looked for. If maize cobs become mouldy, they should be removed and dried in the sun. Grain stored in bags can be checked by its smell. If the grain is going mouldy it will have a bad smell. The grain should be spread in the sun to dry and then stored in clean dry bags.
- The store should be quickly repaired if it becomes damaged. If repairs are delayed a lot of grain may be lost to rats, mice and birds.

Good storage practice is the key to maintaining grain quality. Observing the four pillars described above will help farmers maintain the quality and value of their grain throughout the storage season.

Good warehouse/store management for safe storage of oil seeds and grains

(i)	Selection of site	The storage structure should be located on a raised, well-drained site. The site should be protected from humidity (moisture), excessive heat, insect, rodents and bad weather conditions; and it should be easily accessible
(ii)	Selection of storage structure	The storage structure should be selected according to quantity to be stored. Sufficient space should be provided between two stacks for proper aeration.
(iii)	Cleaning and fumigation	Storage structure should be properly cleaned and there should be no left over of seeds, cracks, holes and crevices in structure. The structure should be fumigated before storage
(iv)	Drying and cleaning	The seeds should be properly dried and cleaned to avoid quality deterioration before storage
(v)	Cleaning of bags	Only new and dry gunny bags should be used
(vi)	Separate storage of new and old stock	The new and old stocks should be stored separately to check infestation and to maintain hygienic condition.
(vii)	Use of dunnage/ palates	Bags of seed should be kept on wooden crates or bamboo mats along with a cover of polythene sheet to avoid absorption of moisture from the floor.
(viii)	Proper aeration	There should be proper aeration during clean weather condition. Aeration in rainy season should be avoided.
(ix)	Cleaning of vehicles	The vehicles used for transportation of sesame seed should be cleaned by disinfectant to avoid infestation.
(x)	Regular inspection	To maintain proper health and hygiene of stock, regular inspection of stored seed is essential.