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STUDY

IMPROVING COMPETITIVENESS, SAFETY AND QUALITY OF HORTICULTURE PRODUCE THROUGH GOOD POST HARVEST MANAGEMENT PRACTICES

A FOCUS ON FRENCH BEANS PRODUCTION IN RWANDA

Co-funded by the European Union

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About the study

Post-harvest management and losses reduction strategies for fine beans from harvest, storage and transportation to processing sites use of simple low cost innovations and the adoption of best practices by producers of fine beans.

The vegetable covered is the French bean or Fine bean (*Phaseoullus vulgaris L*) produced for export. The fine bean crop has been selected as a pioneer crop to increase competitiveness in the horticulture sector considering that in Rwanda it is currently traded at 70% by volume on all product exported by Small and Medium Enterprises (SMEs) to the markets of the European Union (EU) and the United Kingdom (UK). It is also by far the crop mostly affected by post-harvest losses considering an estimated 40%-45% of the production yield is not exported but instead rejected or sold to the local market as second grade produce.

The paper is designed as a handbook, and it was drafted in easy to understand English language with reduced technical terminologies which targets to ensure maximum understanding of the main concepts of post-harvest management and quality maintenance.

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I would also like to thank the NAEB pack house staff Mr. Innocent MWALIMU and Mrs. MUSHIMIYIMANA Annonciata for insights in produce handling at the NAEB pack house facility during product reception by various exporters using the facility.

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Disclaimer

Acronyms

BOPP	Biaxially Oriented Polypropylene
BRC	British Retail Consortium
EAC	East African Community
ETI	Ethical Trade Initiative
EU	European Union
FAO	Food and Agriculture Organisation
FSSC	Food Safety Standard certification
GAP	Good Agriculture Practices
GHP	Good Hygiene Practices
GLOBAL GAP	Global Good Agriculture Practices
GSFI	Global Food Safety Initiative
HACCP	Hazard Analysis Critical Control Points
ITC	International Trade Centre
MARKUP	Market Access Upgrade Programme
MRL	Maximum Residue Limit
MSDS	Material Safety Data Sheet
NAEB	National Agriculture Export Development Board
PHI	Pre-Harvest Intervals
PPE	Personnel Protective Equipment's
PVS	Private Voluntary Standards
RS-HACCP	Rwanda Standard-Hazard Analysis Critical Control Point
SDGs	Sustainable Development Goals
SMEs	Small Medium Enterprises
SNV	Netherlands Development Organisation
UK	United Kingdom
USD	United States Dollar
WHO	World Health Organisation of United Nations
WTO	World Trade Organisation of United Nations

Executive Summary

Horticulture SMEs in Rwanda face a myriad of challenges in areas related to post-harvest handling of produce at harvest in the farm, during storage and transportation to processing sites. Margins are further reduced due to losses associated with high wastages at farms and pack houses due to inadequate technological expertise in preservation, value addition and limited infrastructure. An ITC Market Access Upgrade Programme (MARKUP) value chain analysis study commissioned in 2019 identified various challenges faced by those exporting products to UK and EU. Some of the challenges identified included logistics-airfreight, Agri inputs accessibility, post- harvest losses due to technological gaps, SMEs farming technology gaps, access to finance, market and packaging among others.

According to ITC data, there has been a steady increase in exportation of leguminous fresh and chilled vegetables from Rwanda since 2014 with an increment of 4,520,000 to 39,640,000 United States Dollars (USD) by value. Fine beans are the main crop exported from Rwanda estimated at 70% of the entire export volumes into EU (NAEB 2018).

Horticulture production and processing for export market from Rwanda are posed with numerous challenges attributed to inadequacy in technical know-how (low skills), technological gaps leading to loss of high quantity of exportable fresh fruits and vegetables. The losses have led to reduced profit margins, lower payments to farmers and increase in wastage. A number of farmers have been demoralized by the level of produce rejection and this has led to some farmers quitting production or scaling-down production

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CHAPTER :1 INTRODUCTION

1.1 Scope and Content

This paper will address post-harvest management and losses reduction strategies for fine beans from harvest, storage and transportation to processing sites. It will do so by looking at the use of simple low cost innovations and the adoption of best practices by producers of fine beans.

- **Vegetable covered**: French beans or Fine beans (*Phaseoullus vulgaris L*) produced for export., The fine bean crop has been selected as a pioneer crop for purpose of increasing competitiveness in the horticulture sector considering, it is currently traded at 70% by volume on all product exported by SME'S to EU and UK markets. It is also by far the crop mostly affected by post-harvest losses considering an estimated 40%-45% of the production yield is not exported but instead sold to the local market as second grade.
- **Target organisations**: Small and Medium Enterprises (SMEs) exporting fine beans to European Union (EU) and United Kingdom (UK).

The handbook is designed and presented in easy to understand local Kinyarwanda language targeting to ensure maximum understanding of the main concepts of post-harvest management and quality maintenance.

1.2 Referenced Standards and Code of Practice

The requirements of food safety, good agricultural practices and ideal quality systems in this manual are discussed based on the following Global food safety initiative (GSFI) recognised standards namely:

1. British Retail Consortium (BRC) issue 8;
2. Global Gap version 5.1;
3. Hazard Analysis Critical Control Point (HACCP) Codex Alimentarius;
4. HACCP RS 184:2017;
5. Food Safety Standard Certification (FSSC-22000);
6. Draft Rwanda Horticulture Code of Practice.

CHAPTER 2: BUSINESS CASE FOR IMPROVING POST-HARVEST MANAGEMENT SYSTEMS

Key highlights: Readers are equipped with skills and knowledge on activities within each horticulture value chain to identify the importance of managing losses and the benefits of limiting the losses in fine beans supply chain.

2.1 Business Case for Improving Post- Harvest Management Systems

Large amounts of resources in the form of time and money are required in the cultivation of food produce. Commercial ventures demand more resources and unless the farmer is providing food only, for the family the venture becomes part of the market economy: the farmer engages in trade to recover the costs, and make a profit.

It is estimated that post-harvest losses of fresh produce in the developing world due to mishandling, spoilage and pest infestation are at 40 percent. This means that nearly half of what is produced never reaches the consumer for whom it was grown, and the effort and money required to produce it are lost forever.

In Rwanda, exporters of fine beans face myriad of challenges in trying to make the product competitive. An estimated 40% to 45% of the production volume is lost in between the various stages of the value chain. Saving in any of the stages through the adoption of local techniques makes the product more competitive compared to the present scenario. According to exporter and NAEB post-harvest data (Unpublished) an estimated 50% of the production volume hardly reaches the market. According to research done by Netherlands Development Organisation (SNV) (2017) losses in Rwanda are split into two levels, at production which is noted at 12% while at the pack house losses are recorded averaging 20-30% depending on season with losses during rainy season noted to be as high as 50% of the total production.

Table 1 shows average losses in the different stages of value chain, considering the various costs such as inputs, labour, electricity, consumables among others, used to produce a kilogram (kg) of fine beans. Based on this information it is unlikely that exporters would make any profit margins if more than 40% of the product is diverted to the local market.

Table 1 Average losses in the value chain stages

Value chain stage	Current losses in Kgs	Current average losses %	Current Losses in USD	Losses after improved techniques	Target recovered weight	Recovered money in USD after introduction of new techniques	Cost of sales of grade 2 in RWF
Harvest stage	100	10%	150	3%	70	105	10500
Farm storage	20	2%	30	1%	20	30	4500
Transport	60	6%	90	1%	50	75	7500
Pack house	350	35%	525	8%	270	405	40,500
Shelf life weight adjustment	60	6%	90	2%	40	60	6000
Totals	590		885		450	675	69,000

Note: Assumption 1kg net cost 1.5USD in the market while 1Kg of grade 2 costs 150RWF exit pack house

The reduction of post-harvest losses requires a clear understanding of the factors or root causes contributing to the losses at each stage of the value chain in order for management of respective SMEs to develop strategies that would reduce the levels in phases.

2.2 Causes of Post-Harvest Losses

Fruits and vegetables are composed 65-95 % by water, retaining the water after harvest and continuing the living process as living plants even after.

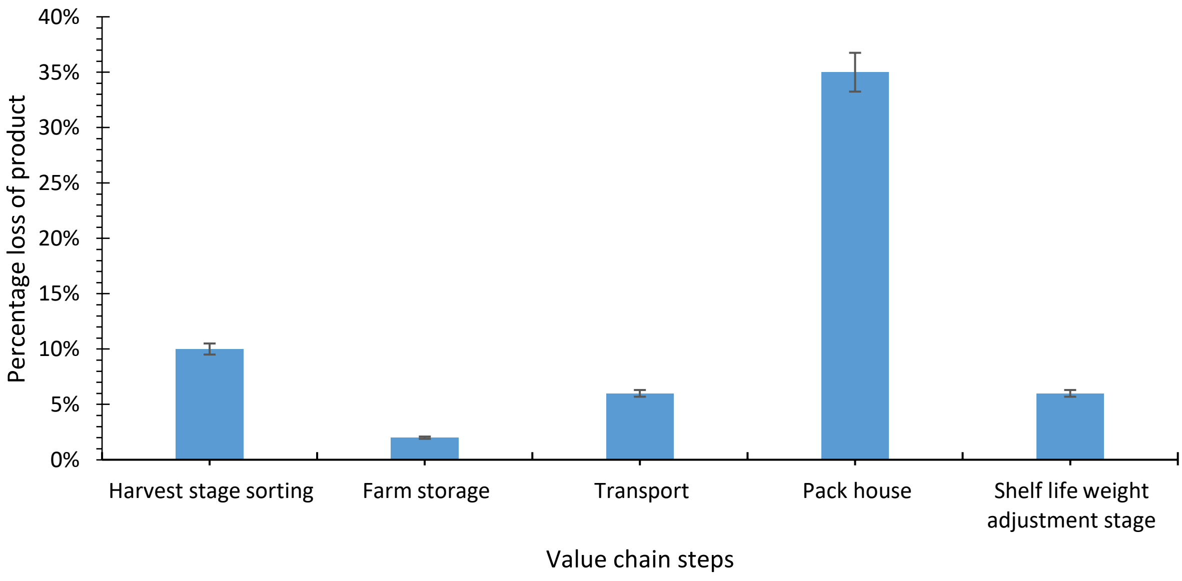
Their post-harvest shelf life depends on the rate at which they use up their stored food reserves and their rate of water loss. Quality deterioration is observed as the plants exhaust the food reserves through a process known as *senesces*. There are various activities that increase the rate of this process making the produce inedible.

Figure 1 shows the current losses at each value chain stage. Among these, the pack house is a significant source of loss (35%) mainly due to operational functions of a grading and sorting facility were primarily product that does not meet customer specification is separated and graded out for disposal, local consumption or used as animal feed.

Various parameters define the quality of a product necessary to meet stringent EU/UK market requirements, which include that the product must be free from diseases and pest infestation, from physical injuries, chemical deposits and it must be within acceptable morphological specification (2% tolerance on curvature and deformities). If the above conditions are met, the raw material accessing the pack house must at least be above 85% pack ability, in order to reduce significantly the losses at the grading stage. T

However, in reality most of the pre-sorting at the farm does not meet necessary threshold resulting in a lot of product not meeting customer specification already at the pack house.

Figure 1 Value chain stages and level of losses



Harvest pre-sorting contributes an estimated average of 10% of the post- harvest losses by volume with a sharp increase as the blocks age (1% new blocks and > 15% old aging blocks), which is a significant loss. In the current situation, SMEs experience losses associated to pest infestation, mechanical damage as a result of using non-complying harvest equipment's (i.e. gunny bugs).

On average SME-exporters in Rwanda experience an average of 6 to 10% losses during transportation of raw materials to the processing site. The losses are attributed to dehydration (weight loss) due to the use of non-compliant modes of transport which cause the product to lose moisture while in transit. The adoption of international best practices is likely to cause a reduction of transport related losses from the current 10% to the recommended 3%. The introduction of equipment such as calibrated scales could have a great impact in ensuring that the weights recorded at farm capture accurate data thus minimizing variance perceived to be a loss.

2.2.1 Introduction of Cost-Benefit analysis in the adoption of improved techniques resulting in the reduction of food losses

The majority of SMEs engaged in horticulture production rely on smallholders, either as individual farmers or organized in form of co-operatives. Due to this, few SMEs have the capacity to do their own farm production. Reducing product loss and waste could offer an opportunity to farmers to save money ensuring: timely payment and competitive export businesses, which would help households feed more people. The adoption of improved techniques target savings by exporters through conversion of losses into monetary gain thus translate to further investments in the sector through:

- Increase market volume and competitiveness of exporters in EU and UK markets;
- Stimulate growth of exporters through increase of profit margins;
- Generate more employment and income opportunities and stimulate the rural economy;
- Promote gender equality as more women are involved in postharvest and marketing operations;
- Increase capacity to acquire small implements necessary for the implementation of better techniques, i.e. purchase of crates instead of using gunny bags for harvesting.

Figure 2 Comparison of saving in percentage between current and after improved techniques

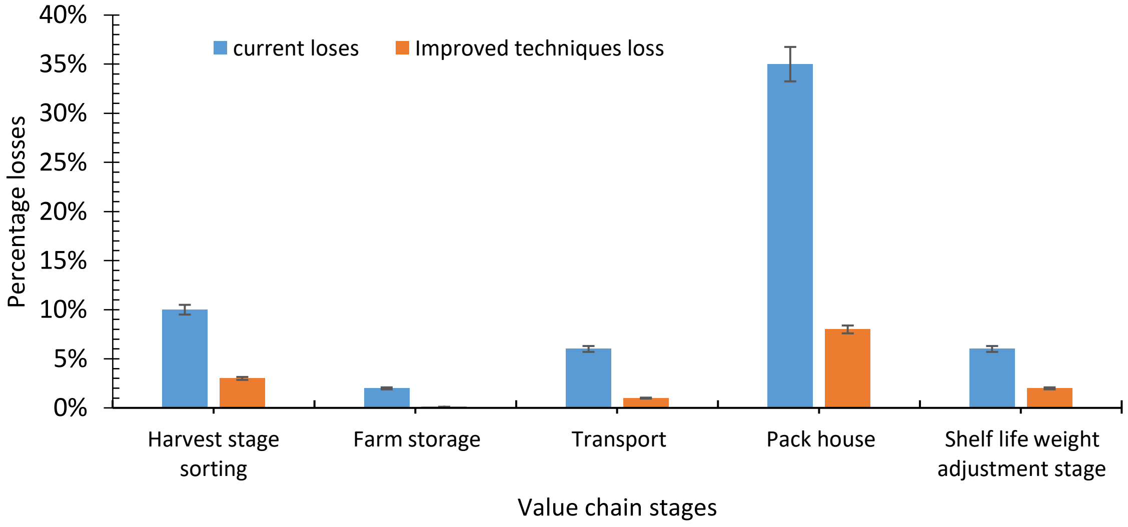


Table 2 Example of cost and benefits of improved technologies

Value chain stage	Current losses	Kg loss	Losses in USD @ 1.5/kg	Type of Improved technology	Units required	Unit cost USD	Total cost (USD) Cost of improved technology	Comments
Harvest stage	10%	100	150	Use of standard crates. Skill improvement. Temperature probes Specification rulers Planting wind breaks	63pcs 2 days 1 5	3.9 200 22.99 4	246.5 400 22.99 20	Pre-harvest tools
Farm storage	2%	20	30	Charcoal coolers Use of shed nets	1 50m	NA 7.5	3000** 375	Shade nets can be used to reduce solar heat effect on harvested products
Transport	6%	60	90	Refrigerated truck. Hire refrigerated truck capacity(5T) Skill enhancement.	1 1 2 days	NA 100 200	55,000* 100 400	Truck purchase too expensive and not visible with current SME's potential hence pool hiring is a better option
Pack house	35%	350	525	Skills enhancement	2 days	200	400	Training to enhance skills will tremendously reduce losses due to product spec issues
Shelf life weight adjustment using Biaxially Oriented Polypropylene (BOPP) bags	6%	60	90	Packaging use of MAP bags improvement/skill enhancement.	2days 2000pcs	200 0.042	400 84	Improvement of packaging from the high respiratory BOPP bags to MAP bags
Total			885				5848.5	

Note * estimated long term investment with an option of hiring from logistics firms, ** estimated one off investment to last for over 5 years

The losses of 885 USD are for 1 tone of fine beans, with an investment of 5146 USD it will take a harvest of equivalent 10T at most to start benefiting from the investment (other operation cost, overhead and input costs are not factored in).

2.3 Value Chain Enhancement

The fine beans production for export value chain activities involve production, post-harvest management, transport and distribution to retailers. Production is a basic part of the chain, which includes the acquisition of inputs (seeds, agrochemicals and fertilizers) through agronomic practices.

An understanding of the value chain is necessary for stakeholders to identify problems and real issues that contribute to overall losses across the value chain. The reduction of losses through a value chain approach has several components. Amongst these, those with direct effect include:

- Value chain analysis for losses at each stage with actors made aware of how their roles and actions have an impact on product quality and safety;
- Building capacity within value chain through the introduction of technologies and non-technology interventions where value chain actors are capacitated through trainings, workshops, benchmarking trips and market linkages in order to understand market requirements thus building competitiveness;
- Adoption of technology through research and implementation of local developed solutions to avert or reduce losses.

The value chain of fine beans is progressively becoming more complex based on the number of entities within the chain. The production of fine beans exhibits some element of the modern chain and post-harvest management chain as discussed below.

2.3.1 Types of chains in fine beans production

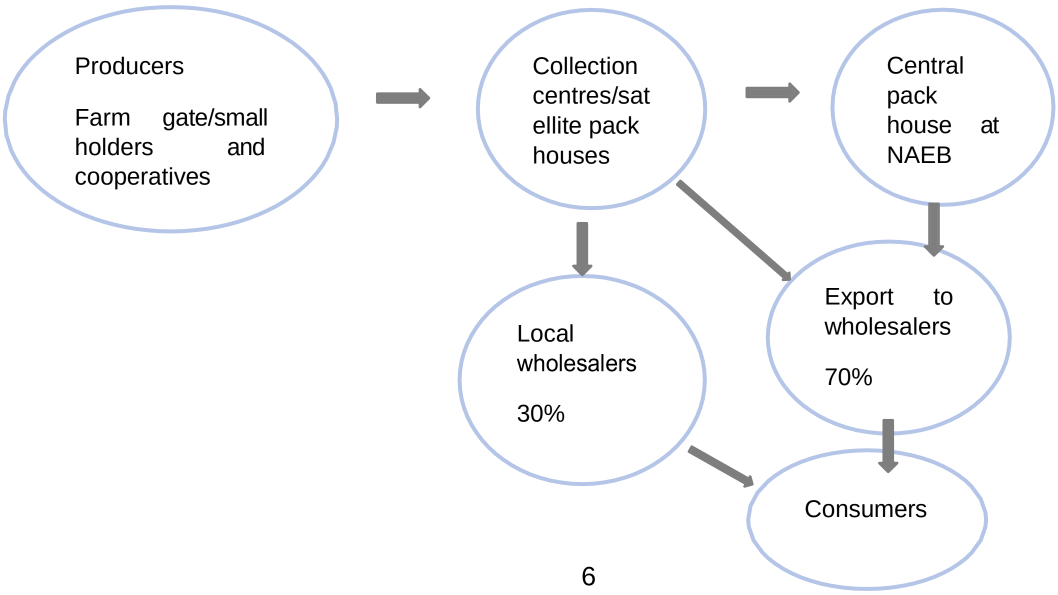
2.3.1.1 Traditional chain

Traditional value chains begin in the local rural (farmer) setup in developing countries, trading on various types of vegetables and grains which target the urban market (supermarkets and wholesalers). Traditional chains are known to be complex with a high number of intermediaries leading to increased cost of commodities.

2.2.1.2 Modern chain

The modern value chain involves trans and cross border trade, governed by international trade practices, mainly due to demands across the borders for commodities. Rwanda's fine beans production is practiced mainly for transcontinental export which is driven by the customer requirements fetching more margins compared to trans-border trade, hence more organised as opposed to the traditional value chain. Fine beans fall under what is called the "modern value chain".

Figure 3 The modern value chain of fine beans



Producers for this specific crop are mainly contracted by established exporters, where the contractor guarantees a ready market and a fixed price for the fine beans. The harvested product is either processed at the collection centre and then delivered directly to the airport for trans-continental shipment or temporally stored and transported to the NAEB pack house (Shared facility) for cooling, sorting, grading, cooled again and finally packed for air shipment to various destinations (EU, UK and UAE).

High standards and a hygienic environment is required to control microbial, physical, allergen and chemical hazards and ensure desired quality in food product.

Under advanced modern value chain of fine beans, a vertical integrated export mechanism in presumed, where established or middle level exporters are able to produce, pack, ship and distribute the commodity to supermarkets or wholesalers directly without relying on intermediaries in importing countries.

2.2.3 Fine beans post- harvest value chain and associated losses in each stage of the chain

A post- harvest chain of fine beans involves activities starting from the farm prior to harvesting, storage, transportation to the pack house, pre-cooling sorting, grading, packing, cooling and airfreight. All these activities must be done within a tight cold chain management to minimise post-harvest losses.

Harvest stage

Pre-harvest causes contribute to an average 10% of losses on the entire life of a production cycle of a fine beans crop. Some of the causes of the losses are pests and disease attacks on crop and environmental changes such as high rain leading to floods, especially were farmers engage in production in marshy areas. Other pre-harvest causes include abrasion damages occasioned by extreme exposure of the crop to wind with high speed leading to scarring. This phenomenon can be prevented thanks to the adoption of biological barriers (as the wind breaks the crop). The rate of loss is correlated to the aging of the crop, such that at fly pick the losses observed are as low as 1% of the gross weight picked. However, as the block age through, production losses increase to as high as 15% in the 16th harvest pick of a block leading to the average 10% farm pre-sorting loss.

Field storage

Field temporal storage is an important stage in the value chain. If improperly handled it leads to the exposure of the crop to adverse conditions and a rapid deterioration of the quality of fine beans. Storage conditions with high temperature lead to dehydration (weight loss), which is a serious cause of loss.

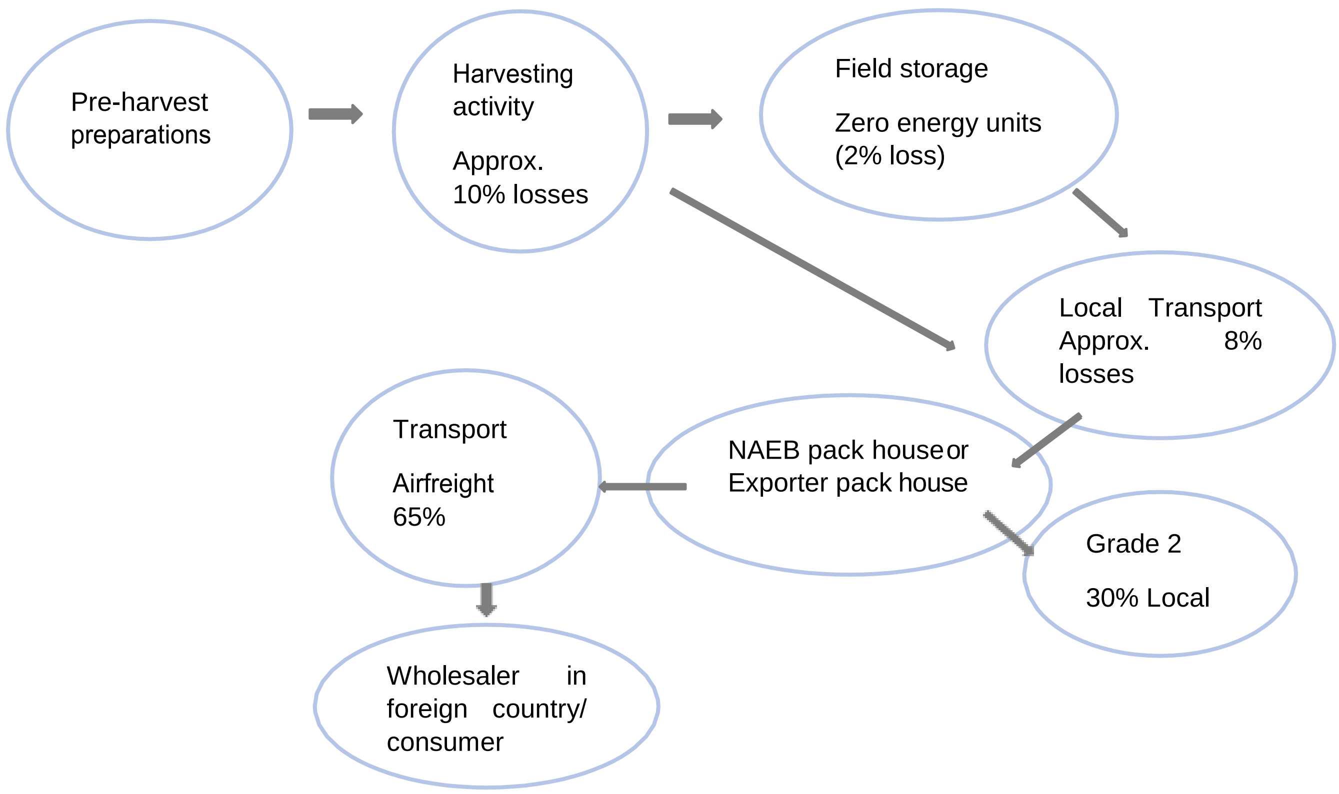
Inter farm – transport

Since most of the exporters source fine beans by contracting farming involving smallholders, producers of fine beans are scattered across Rwanda, which leads to a challenge of the aggregation of the crop before its transportation to the sorting and grading site. The mode of transportation currently in use contributes significantly to product deterioration leading to an average 6% losses of crop. The losses are attributed to the use of non-temperature controlled modes of transport, open trucks leading to introduction of dirt (dust) on harvested crop, uneven road infrastructure between farmers and collection centres which cause vibration damages.

Pack house stage

In the current situation, pack house losses contributes to a range of 35- 40% of the losses of gross product delivered (NAEB Pack house data). Varying causes lead to such high levels, which include out of specification product (over spec-bobby beans), curved beans that are out of tolerance limits, dehydrated pods, pest and disease infested pods and mechanically damaged pods, as a result of poor handling. The pack house in itself contributes to some level of quality deterioration due to the infrastructure itself (i.e., absence of insulation on the processing side). The reduction in losses at the pack house stage will require the implementation of improved techniques at the farm level such as improving infrastructure. This entails the development of zero cooling units at the farm level, protection of harvested crop from direct sun heat and use of recommended harvesting equipment.

Figure 4 General activities for a fine beans post-harvest value chain (losses estimate based on data of exports from NAEB pack house)



2.4 Market Requirement

Export activities are governed by international, bilateral and multilateral agreements between member states or trading blocks with the specific legislation of importing countries for each commodity. The major destinations for produce from Rwanda are the EU and the UK, and therefore all exporters must meet the legislative requirements of EU and UK. These requirements are considered demanding and difficult to implement for the exporting company without external support.

Market requirements are classified as legislative, commercial and social. Their main goal is to ensure the supply of safe, quality and environmental friendly products, while guaranteeing the social welfare of producing staff.

Food safety requirements

These are restrictions relating to the use of banned or restricted pesticides and the presence of residues of molecules that are approved (Maximum Residue Levels (MRLs)) and used for pest control, but, if present in the produce at the time of sampling and above the allowable levels, they expose the consumer to food safety risk. The presence of pathogenic microorganism hazards in food is a major food safety concern. Therefore, there is a market access requirement to ensure any presence meets the set criteria.

Product quality requirements

Quality attribute requirements relate to product specifications that are determined by the market. The market categories for fine beans are 1, 2 and 3, and each category fetching different prices.

Social, environmental and business compliance

The export market of fresh produce to the EU and the UK requires producers to comply with strict social and environmental standards, even though most of the social and environmental standards are based on voluntary compliance, like Fair Trade, Ethical Trade Initiative (ETI), Good Hygiene Practices (GHP) and Rainforest Alliance attract premium price on commodities certified as compared to non-certified commodities. Some grocery stores prequalify suppliers based on certification status to any of the social and environmental standards before engaging in any business with new suppliers.

Plant health requirements

All plant material exported to the EU is required to comply with EU legislation on plant health, which includes a declaration through a phytosanitary certificate of the “clean” nature of the material intended for entry into EU and their freedom from harmful, restricted or invasive organisms.

Customer and statutory requirements discussed in chapters three and four.

CHAPTER 3: FOOD SAFETY AND GOOD AGRICULTURAL PRACTICES IN POST-HARVEST MANAGEMENT

Key highlights: Enables the user to understand food safety requirements in a farming setup and the impact of quality on fine beans production. It also addresses the cost and benefits of investing in a food safety management system.

3.1 Food Safety and Good Agricultural Practices in Post- Harvest Management

Good management of produce during production both pre and post-harvest is key in assuring the safety and quality of the food along the value chain.

Food safety is defined as an assurance that the food once prepared or consumed in accordance to the intended use by consumers will not cause any adverse effect to health (FAO, WHO 1997).

Food safety is an obligation for all the players in the food sector: growers, producers, processers, transporters, exporters and importers among others along the value chain. Responsibility for food safety and quality along any food value chain is a shared responsibility to ensure that the food placed on the market meets wholesome attributes which include:

- The food does not have a harmful effect on the consumer;
- The food meets regulatory and current requirements;
- Defective food can be easily withdrawn through recall, in case it is found to be defective.

To reduce risks and increase market shares, farming activities require the implementation of systems to control hazards, build capacity and assure consumers of the safety of the product.

In trans-continental trade, consumers and markets determine applicable standards as a criterion to access the market. These standards are commonly referred to as private voluntary standards (PVS). An example is the EU and UK grocery stores that prefer trading with partners that have implemented BRC, Global GAP or any GFSI recognised standard, demonstrating an assurance that the food produced by suppliers or SMEs meet food safety certification requirements. While some markets do not emphasise on supplier conformance to PVS, most EU and UK dealers in fresh fruit and vegetables recognise and emphasise supplier certification through PVS schemes.

The majority of PVSs require financial resources to implement most of the infrastructural needs, improve staff awareness through training and coaching and additional finances for the actual third party certification audits. These resources are not easily accessible for SMEs, and an additional investment cost would eventually render the product less competitive. On the contrary, grocery stores in the EU and UK who require PSV, do pay premium prices for certified commodities with a guarantee of long term market and as such the benefits of implementation and adoption of the food safety schemes outweigh the investment costs.

3.1.1.1 Food safety policy and objectives at farm level

A farm food safety policy is a declaration that reflects in an unambiguous manner the commitment by a producer to ensure that food safety requirements are implemented and maintained throughout the process of food production at the respective farm.

Some of the key requirements in the food safety policy include setting up of realistic objectives that are time bound (reviewed) at a set period of time, measurable and simple. The food safety policy must be signed by the senior manager of the farm or organisation, thus committing the management to the implementation and maintenance of the food safety system requirements.

For organisation that have many members (groups) that are organised in form or co-operatives with implemented QMS in place (option 2 in Global GAP) may have a central management that assumes the commitment for all its members by committing and signing one declaration at the QMS level.

3.2 HACCP at farm levels- Risk assessment, Hazard identification and controls

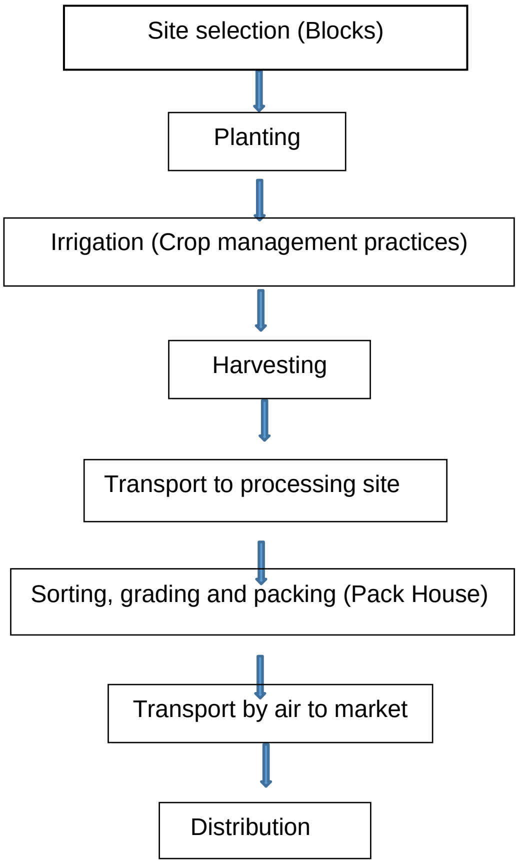
Food safety works best when a system approach is introduced in any food production venture. The *Codex Alimentarius* recognises the HACCP system as the fundamental basic requirement.

A product flow diagram describes what happens in the various stages, from primary production to final product distribution. A detailed analysis of activities at every stage in the product flow is the first step for the development of an effective food safety system.

The fine beans flow diagram (Figure 3.1) is the main tool in food safety. It is used to evaluate potential risks and dangers at specific points where control actions are needed, as well as determine appropriate critical control points for action.

The identification of hazards takes place at each stage of product handling within the product flow and mitigation measures are taken to prevent or control the hazard.

Figure 5 Product flow of fine beans



3.2.1 Hazards in fine beans production flow are classified into three broad forms

Physical hazard

Such as stones, glass, hair, jewellery and soil (mud).

These are foreign materials in fine beans that are likely to cause life threatening or permanent injury once ingested by a consumer through choking or dental injury. Most of the physical hazards result from poor practices during harvesting, sorting, grading and packing (FAO 1998). A system approach through development of pre-requisite programs should adequately prevent their entry into the food during production, processing and distribution.

Chemical hazards

Chemical hazards are either naturally existing in food or introduced during production, post-harvest, transportation or at a distribution point. High exposure to harmful chemicals has been associated with acute toxicity leading to health complications in consumers after a long period of time (the consequences are not immediate).

Some of the common agents that could lead to toxicity include: pesticides above MRLs, fertilizers, antibiotics, toxins, heavy metals, oil and grease.

Microbiological

Food- borne causal agents that are biological in nature are classified as ether bacterial, fungal or parasitic in nature. Some fungi are able to produce toxins in food (e.g. *Aspergillus niger*) leading to aflatoxins, zearalenone, fumonisins, patulin and ochratoxins A among others.

Based on tropical environmental conditions, microorganisms exist as incidental contaminants in produce or as part of the microflora introduced to produce through soil, dust and surroundings. In some instances, the microorganism is introduced in the produce through poor production and handling practices such as the use of manure, contaminated water for irrigation and through post- harvest unsanitary handling of produce.

Some of the common pathogenic bacteria likely to cause food safety concern from fine beans include:

Table 3 Common pathogenic bacteria in fine beans

Pathogenic micro-organism-Hazard	Health implications
Escherichia coli (EHEC strain -Pathogenic strain) Shigella spps Streptococcus aureus Listeria monocytogenesis Clostridium perfringens Campylobacter species Salmonella spp Vibro spp	Gastrointestinal and enteric disease. Gastrointestinal diarrhoea with blood Pneumonia toxic shock syndrome Listeriosis disease Gastrointestinal diarrhoea/stomach cramps Nausea, bloody diarrhoea and fever Dizziness, fever, constipation, loss of appetite Abdominal pain, vomiting, diarrhoea

Table 4 Physical hazards

Hazard agent	Specific risk	Reason for occurrence	Likely control measure
Physical hazard through:			
Staff-Worker	– Jewellery – Elastoplast – Hair – Nail polish – Nail fragments – Strings	– Personnel control prior to harvesting not effected; – Inadequate awareness among personnel performing harvesting activity;	– Training of personnel on food hygiene and sanitation; – Proving PPEs to harvesting teams;

	– Cigarette buts	– Inappropriate or luck of working Personnel protective equipment(clothing).	– Hygiene checks by supervisors before harvesting; – Clear signage's on dos and don'ts at the farm.
Equipment and harvest containers	– Knives – Crates – Wood – Glass – Plastics – Metal	– Insufficient cleaning of knives; – Low or no monitoring and withdrawal of damaged crates; – Inadequate maintenance of equipment; – Discarding all glass and plastics in farm.	– Develop and monitor cleaning schedule; – Examine and servicing of equipment before they are used for harvest.
Soil	– Soil – Stone particles in finished product	– Harvesting beans immediately after rains or in the early morning; – Transportation of beans in open trucks.	– Wash beans using potable water with chlorine; – Do not harvest in rainy conditions, wait until excess water has evaporated from crop; – Use of closed trucks to transport produce.
Machinery	– Soil – Stone – Metal	Dirty equipment	Cleaning schedule for all equipment.

Table 5 Chemical hazards

Hazard agent	Specific risk	Reason for occurrence	Likely control measure
Chemical hazards			
Detergents	Use of perfumed tainted soap and sanitizers	Insufficient knowledge on appropriate detergents and sanitizers.	Only use approved chemicals with MSDS indicting food grade nature of detergents
Pesticides	MRL Exceedance	– Inappropriate use of pesticide.	Follow EU and local regulatory requirements.
	Use of banned and unapproved pesticide residues	– Wrong pesticide selection; – Non-observation of harvest interval as per label; – Wind spray drift; – Incorrect dosage; – Use of faulty spray equipment; – Use of contaminated water during pesticide mixing.	– Develop approved list for each crop; – Follow label recommendation for pre-harvest interval; – Training of spray team on safe use of pesticides; – Planting of buffer zones along blocks; – Ensure weather conditions are appropriate for spraying; – Calibration of spray equipment.
Grease and oil	Oil and grease taint	– Use of produce containers to store fertilizers, lubricants or oil; – Fuel spillage on ground or produce during farm activities.	– Restrict use of produce containers to dedicated use; – Proper disposal of chemical container (puncture empties);

			– Proper servicing of farm equipment.
Heavy metals	Heavy metal residue	Through water and soil	Periodic soil tests and isolate contaminated sites.

Table 6 Microbes spreading agent

Hazard Agent	Specific risk	Reason for occurrence	Likely controls measures
Microbes spreading agent			
Staff and visitors	Staphylococcus aureus	Workers not observing personnel hygiene leading to contamination at harvest.	Training of workers on personnel hygiene. Notification to visitors and contractors on rules before entry.
Animal manure	E-coli	Contamination from livestock or human sewage as a result of flood or use of contaminated irrigation water.	Adequate Drainage, appropriate site selection. Testing of irrigation water.
Water	Salmonella	Use of untreated water	Periodic water testing
Domesticated animals	Campylobacter Listeria spp	Poor waste management, poor temperature management.	Restriction of domesticated animals.
Spread of slurry	Vibro	Use of sewage water for irrigation	Avoid use of slurry as manure
Decaying matter	Clostridium	Incomplete composting of green manure	Test of manure before use in crops.

3.3 Traceability

According to the *Codex alimentarius* traceability or product tracing is the ability to follow the movement of food through specified stages of production, processing and distribution encompassing the concept of tracking and tracing.

I. **Tracking,** which refers to the ability to determine in real time the exact location and status of the produce in the logistic chain;
II. **Tracing,** which refers to the ability to reconstruct the historical flow of produce on the basis of records maintained throughout the chain.

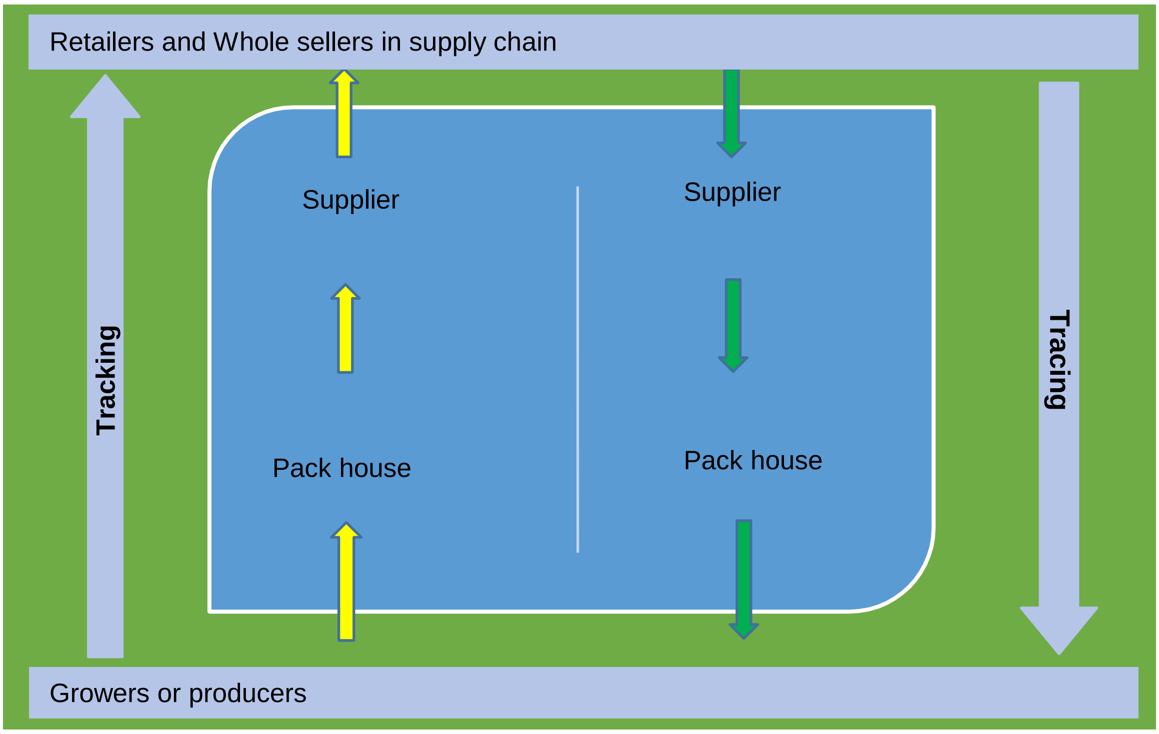
3.3.1 Why is traceability important

A properly designed traceability system provides an important element of **Quality** and **Safety Assurance** in the horticultural supply value chain. The product can be traced back through the supply chain to the site of production, including the various types of inputs used, operations undertaken during production, post-harvesting activities storage and marketing. It also allows the product to be tracked as it moves through the chain from the producer to consumer.

Traceability facilitates the recall or withdrawal of food items enabling customers to have targeted and accurate information concerning implicated products within a short time. In a farm with systems a documented traceability system allows the tracing of produce to the registered farm or a group.

Harvest information links a batch along the value chain to the production records or the farm's specific producers. At every stage of handling of farm produce the traceability information needs to be maintained.

Figure 6 Traceability flow in a horticulture supply chain



3.3.2 What are the main components of traceability?

A functioning traceability system includes a documentation system and mechanisms for marking the produce, thereby allowing it to be followed from the farm (grower) to the consumer. Either an electronic or hard copy of a record form must be kept at each step i.e. the field, at the pack house, at the supplier and the retailer, and during transit (air, road or sea) from each of these points.

3.3.3 How can small-scale farmers implement traceability?

At small-scale farmer's level, a simple handwritten product label and hand written record at various steps in the chain is recommended (Figure 7 and 8).

Figure 7 Sample traceability tag on a block

Figure 8 Traceability info on crates of fine beans

3.4 Personnel Hygiene and Sanitation

Farm workers are fundamental for the prevention of product contamination. Staff, visitors and contractors should ensure product quality and safety is maintained. Education and training support progress towards ensuring a culture of observance of good practices to diminish hygiene risks by making workers understand the requirements.

The farm should develop a documented hygiene risk written assessment for hygiene issues covering the entire production environment.

These hygiene procedures are key to the implementation of requirements to guarantee food safety. The procedures should at a minimum address risks associated with hazards through the following:

- The need to wash hands;
- The need to cover skin cuts resulting from an injury;
- Limitation of smoking, eating and drinking at designated areas;
- Notification of any relevant infections through screening of staff, visitors and contractors by inquiring on signs of illness such as vomiting, jaundice and diarrhoea. Workers displaying such symptoms should be restricted from direct contact with produce and food-contact surfaces;
- Notification of product contamination with bodily fluids;
- Use of suitable protective clothing during produce handling.

Trainings are mandatory at the minimum to achieve adequate quality and safe products. Use of signage demonstrating control measures is highly recommended to ease understanding among staff, visitors and subcontractors.

Some of the common signage includes:

3.5 Farm Hygiene and Sanitation

Recent food safety related crises in the world, such as the mad cow disease and the avian flu have made consumers demand better guarantees from producers, traders and value chain actors dealing in food on safety of commodities, farmers are obligated to guarantee, take responsibility and innocuousness of product they produce for the markets.

Since food safety risks can originate at production, packing, or transportation levels strict hygiene observance at primary production level is critical. More importantly, most fruits and vegetables are eaten raw thus posing a greater level of risk to the consumers if the hygiene practices are not followed.

Several activities at the farm level must be considered to ensure reduction of potential hazards likely to affect food safety.

3.6 Pest Control

Pests and vermin are defined as any living organism that feeds on produce either at pre-harvest or post-harvest level. Apart from being a source of economic loss, pests are transit vehicles for the introduction of disease causing pathogens into produce.

Most common pest at farm level including rats (rodents), fruit flies, moths and flies require controls through pre-requisite programs such as installation of traps, monitoring bait stations and use of integrated pest management protocols to manage presence of pests.

Apart from having the potential to transmit diseases, pests can disrupt trade among trading partners if not adequately managed. A number of pests are classified as quarantine or restricted pests, which are not allowed to be present in any plant products being imported or exported among the trading partners with Rwanda. Some of these include white flies (*bemicia tabaci*) that affects fine beans among other crops, African cotton leaf worm (*Spodoptera littoralis*), Corn earwarm (*helicovepa zea*) that affects fine beans among other crops.

Common farm pest of economic importance

Figure 9 Cockroaches

Figure 10 Rodents rats and mice in field

Figure 11 White flies (Bemisia tabaci)

Figure 12 Moth (Maruca vitirata)

Figure 13 Leaf minor on beans - larvae (Liriomyza sativae)

Figure 14 Leaf minor on beans- adult fly (Liriomyza sativae)

3.7 Allergen Management

Food allergens are defined as substances that, once ingested by a consumer, are likely to cause body health reactions, which in some individual could result to life threatening complications. All foods have the potential to cause allergic reactions, however there are certain foods that can have serious health effects for consumers.

In the EU there are 14 food materials classified as allergens, which are subjected to labelling requirements by legislation. These include: celery, mustard, cereals containing gluten, eggs, molluscs, fish, sesame seeds, peanuts, shellfish, soy, sulphur dioxide.

Allergens in fruits and vegetables are not complicated and cooking destroys many of the allergenic properties of vegetables and fruits. However, peanut or soy traces are a concern in vegetable production especially in instances where the same facility handles known allergenic products.

Efforts should be made at the farm level to restrict handlers from handling allergens during fine beans harvesting.

Figure 15 Peanuts likely to contaminate fine beans when intercropping in a block

Figure 16 Macadamia nuts should not be planted in fine beans growing area

3.8 Food Fraud and Defense

Food defence refers to mitigation measures undertaken by a producer to prevent intentional introduction of a food safety threat. Food defence is science-based through application of a risk assessment with all potential threats identified and measures undertaken as preventive hazards introduction to food actions. Some simple actions to undertake food defence include the use of lockable trucks while transporting raw materials, packaging and finished products to prevent deliberate and intentional food contamination.

Food fraud refers to deliberate and intentional substitution, addition, tampering, or misrepresentation of food, ingredient or food packaging; or false or misleading statements made about a product for economic gain. An example in fine beans production is the topping up of extra fine beans on fine beans crates, with the intention of indicating supply of fine beans through ‘top dressing’. The price of extra fine beans is overall higher.

3.9 Trainings, Documentation and Record Keeping

Documentation and record keeping is key to implementation, follow-up and evidence of a working system at the farm. For farms aspiring to comply with certification requirements, producers are required to keep up-to-date records for a minimum of two years. For initial inspection for compliance (Global GAP) a minimum of three months’ records are required. Records can be in hard copy or electronic, however electronic records must be backed up for easier retrieval.

Trainings form a critical component on awareness and ensuring systems are maintained in accordance with international best practices. The key areas of training in post-harvest management are critical at farm level. These include:

- Personnel hygiene and sanitation;
- Safe use of plant protective products;
- First aid;

- Harvest procedures, quality control, hygiene and sanitation of produce.

3.10 Water Quality at Farm Level

Water is a basic raw material needed to produce food. Water accessibility, availability and authorization for use are therefore key requirements in fine beans production ventures. Water quality affects the quality and safety of produce. It is necessary to undertake a risk assessment on the quality of water for it to be used in crop production. This will determine if the water is fit for safe production of produce.

Water quality is affected by physical, chemical and microbiological contamination.

Most of the chemical contamination of water comes from the use of plant protection products and chemicals, while physical contaminants include introduction of stones, excessive soil and glass. Microbial contamination may result from activities such as upstream contamination from sewage and animal farms.

An evaluation is necessary to determine potential contamination, which may lead to the need of treatment before use. It is important to be aware of the maximum microbiological acceptable thresholds of most faecal indicator microbes such as E-*coli* and thermos-coliform bacteria. The World Health Organisation (WHO) guidelines on drinking water can be used as a guide on water quality.

It should be noted that reclaimed waste water can be used for fine beans washing, if it complies with WHO guideline on safe use of waste water excreta in agriculture and aquaculture 2008. Analysis results for all water should be recorded.

Figure 17 Use of Lake Muhazi (Fresh water) water for fine beans production

CHAPTER 4: FACTORS CONTRIBUTING TO DETERIORATION OF FINE BEANS QUALITY

Key highlights

The chapter equips the reader with technical awareness on the various factors that contribute to deterioration of quality, the origin of such factors and likely impact on produce.

4.1 Factors Contributing to Deterioration of Beans Quality (Abiotic And Biotic)

Causes of deterioration crop losses are broadly classified into **abiotic** (non-living causes) and **biotic** causes (living).

4.1.2 Abiotic

4.1.2.1 Mechanical factors (mechanical damages due to handling by personnel and equipment)

Mechanical damage can be in form of cuts, bruise or deformation, which often results in skin discoloration. Mechanical damage or physical injury increases processes of respiration, water loss, ethylene production and susceptibility of produce to microbial infection from the cut or injured section. These damages affect nutritional characteristics, shelf life and sensory quality of the fresh produce. In fine beans, the damages are caused by the use of non-compliant harvest equipment and handling, including use of gunny bags, poor stacking of product, uneven transport modes, excess products in crates among others. Generally, the damage may be due to impact, compression, abrasion or vibration.

Figures 18-21 below showcase some of the causes of mechanical damages in beans.

Figure 18 Harvested fine beans in correct crates

Figure 19 Fine beans harvesting in gunny bags leading to excessive condensation and compression damage

Figure 20 Correctly filled crate >16kg on standard crate

Figure 21 Fine beans in jumbo crates weigh >27kg (Compression damage)

Mechanical damage may be due to impact, compression, abrasion or vibration.

4.1.2.2 Compression damage

Such damage occurs when the produce is subjected to heavy weight, with or without physical movement. This takes place when containers used to hold produce are of inappropriate depth, improperly packed produce or stacked too high therefore exerting pressure on bottom layer (use of jumbo crates in fine beans), over-packed, or produce is held in containers with poor structural integrity like gunny bags. It generally, results in distortion, cracks in the produce and splitting.

Figure 22 Correctly filled fine beans crate

Figure 23 Over filled fine beans crate

4.1.2.2 Abrasion damage

This occurs when surfaces of produce slide across another surface causing friction. It can result in removal of the cuticle and wax layers of produce. In fine beans wind has been reported to cause scar marks on pods as a form of wind rub. As a control, the use of wind breaks by planting vegetation along crop blocks is recommended to reduce the wind's speed.

Figure 24 Scars in fine beans due to wind rub

Control: Use of wind brake vegetation along crop blocks is recommended to reduce wind velocity.

4.1.2.3 Impact damage

This type of damage occurs due to collision between produce items or between produce and a hard surface as well as due to rapid acceleration or deceleration, i.e. when produce is dropped. It results in bruising with or without skin injury. This type of damage occurs in fine beans as a result of poor handling during truck loading.

4.1.2.4 Vibration damage

This is a type of damage associated with transport and it occurs when the produce moves repeatedly and on rough road for prolonged periods within a container during transport. Vibration may lead to compression damage, impact or abrasion damage.

To control it, it is advisable to ensure levelling of roads accessing the fields to reduce damages associated with vibration, while also ensuring the vehicle suspension system is well serviced. Truck loading needs to be done in such a manner that ensures that containers are properly secured and that there is no free movement resulting in vibration during motion.

4.1.3 Environmental factors (including temperature)

Environmental factors such as wind speed and temperature contribute to quality properties of produce, through effects on respiration, ethylene metabolism and water loss during crop growth.

High temperature and low humidity increase the rates of physiological processes in most vegetables leading to the dehydration of the produce. To mitigate this, timely cold storage and high humidity storage are employed to slow down these processes and prolong shelf life.

Low temperatures cause physiological disorders leading to freezing and chilling injury (surface discoloration; pitting) low oxygen and/or too high carbon dioxide in storage or package cause physiological disorders due to fermentation.

For fine beans, the recommended storage temperature ranges from 5-8°C while oxygen and carbon dioxide levels are best at 3-5% and 5-10%, respectively.

4.1.4 Biotic factors

4.1.4.1 Microbiological factors (Fungi, bacteria, parasites and viruses in crop)

Microbes are the main source of spoilage of fruits and vegetables. The majority of postharvest diseases of vegetables are caused by bacteria, while in fruits they are caused by fungi.

Diseases lower the quality of produce and cause significant losses to farmers. It should however be noted that most of the diseases observed during the postharvest period may be caused during pre-harvest.

For those diseases whose symptoms develop at pre-harvest time, it is possible to successfully remove the affected produce during harvesting. On the contrary, for those diseases whose symptoms develop after harvest, it is difficult to detect the produce prior to packing and shipping. The symptoms only show up when at the consumer (e.g. cases of anthracnose Figure 25 and moulds Figure 26) resulting in rejections of the whole consignment which causes significant losses to the producer. It is also noted that grading and packaging during wet seasons has more rejections as a result of diseases compared to dry seasons.

Contamination of produce can also occur at pre or postharvest if not properly handled. Microbial contamination can be transmitted through improper cultural practices, by workers and through contact with soil and unclean surfaces. Harvesting containers contaminated with spores of microbes may be a source of infection to clean produce. Thus, quality management should consider both production and postharvest factors.

Figure 25 Anthracnose (Colletotrichum lindemuthianium) on beans

Figure 26 White or grey moulds (Sclerotinia sclerotiorum) onFine beans

It is advisable to maintain hygiene at the farm level to reduce spread of inoculum.

Controls include cleaning of harvesting equipment and pre-harvest spray prophylactic sprays application especially for fungal infestation.

4.2 Physiological Factors (Respiration, Transpiration, Biochemical-Ethylene Emission)

4.2.1 Physiology

Harvested vegetables (including fine beans) are composed of living cells and tissues. During harvesting, the cut part is separated from the growing medium, hence the harvested produce has to continue living on stored reserves in form of carbohydrate and water. Depletion of carbohydrates through respiration and loss of water through transpiration lead to quality loss and produce stress. Produce stress stimulates higher production of ethylene and change of produce colour as a result of senescence hormone, leading to significant quality deterioration.

The basic awareness of physiological processes in produce after harvest is important for the effective maintenance of product quality and the prolongation of the shelf life of the produce.

4.2.1.1 Respiration

Respiration is defined as the breakdown of carbohydrates into carbon dioxide, water and heat in the presence of oxygen (Figures 27 and 28 excess condensate build up in polyethylene packaging):

The implication of this is that by reducing 0_2 or increasing $C0_2$ level (e.g. modified atmosphere packaging, surface coating and controlled atmosphere storage) respiration is diminished, which allows the preservation of quality and the extension of shelf life of produce. However, too low 0_2 and/or too high $C0_2$ levels lead to anaerobic respiration (fermentation) causing physiological disorders and alcoholic flavour (off-flavour) resulting in reduced shelf life of produce.

It is advisable to pre-cool produce and remove the field heat as much as possible, though the process has to be gradual with a goal of limiting cellular shock (chill injury).

Figure 27 Condensation in fine beans punnet due to insufficient pre-cooling

Figure 28 Higher levels of condensation in fine beans packed in bags due to insufficient pre-cool.

4.2.1.2 Effects of uncontrolled respiration of fine beans

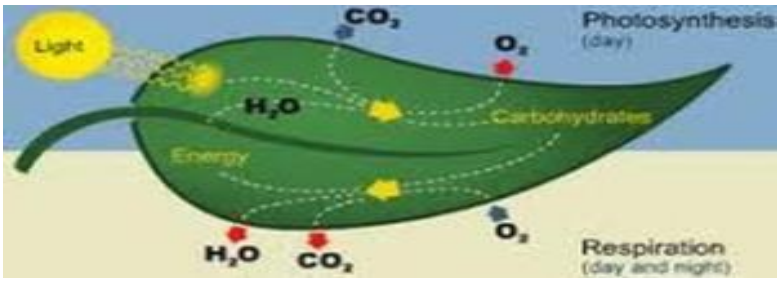
- Accelerated respiration occasionally causes losses in the form of dry weight, quality deterioration, texture and flavour of fine beans.
- Fine beans, just like many vegetables, are non-climacteric and they do not experience final respiratory acceleration before they senesce or completely deteriorate in quality.

- The higher the respiration rate, the faster the rate of quality deterioration and the shorter the shelf life of produce.

Table 7 Rate of respiration of some common produce.

Non Climacteric produce	**Climacteric**	**Relative rate**	**Respiration rate @ 5^0C (mg CO_2 /kg.h)**
Carrots, cauliflower, salad onions, leeks, lettuce, lima beans, ginger.		High	20-40
Cucumber, sweet pepper and celery	Tomatoes	Moderate	20-40
Dried fruits and vegetables	Dates	Very low	<5
Root tubers: Potatoes, cassava, onions, garlic		Low	05 to 10
Fine or Snap beans, Broccoli, Okra, bean sprout, baby corn, Brussel sprout	Paw paw	Very high	30-60
Garden peas, Asparagus, Mushroom, spinach, sweet corn, cut vegetable mixes.		Extremely high	>60

Figure 29 Respiratory processes in leaf of fine beans



4.2.1.3 Ethylene production

Ethylene (C_2H_4), is a gaseous plant hormone that initiates and accelerates the ripening of produce through a change of colour also termed as senescence. All plant tissues produce ethylene at varying rates. Fruits produce higher ethylene, when compared to vegetables, however vegetables are sensitive to ethylene, thus it is recommended to never mix vegetables with high ethylene produces such as bananas, passion fruits, avocados and other fruits.

When fine beans are exposed to prolonged ethylene, yellowing of beans is noted. The control of ethylene emission and effect in acceleration of ripening can be overcome through initial pre-cooling and later cold storage of the produce, and temperatures between 5 to 8^0C are recommended for fine beans storage.

Figure 30 Separated fine beans and other products

Figure 31 Mixing of fine beans and passion fruits in same cold store

Product segregation between high emitters of ethylene, moderate and low emitters is advisable.

For advanced storage, or long distance transportation such as sea transport, ethylene absorbers (potassium permanganate($KMnO_4$) or scrappers/inhibitors (Methyl cyclopropene or 1-MCP) are recommended.

4.2.1.4 Transpiration

Transpiration in produce is the action of loss of water through cellular activities from the produce, which is also referred to as evapotranspiration, where water change from liquid to vapour in the presence of heat.

Produce loses water due to an increase of pressure in the inner cells of produce compared to the environmental pressure, also referred to as relative humidity level and usually about 98-100% in produce leading to systematic collapsing of cell (dehydration).

To reduce transpiration (water loss) it is advisable to increase relative humidity of the storage environment to about 80% and lower the temperature of the surrounding this forms a surface burrier limiting loss of water thus controlling dehydration of produce.

Crops have several mechanisms to control loss of water, such as including waxy surface that reduces the rate of transpiration. This is the case of fine beans varieties that are waxier which tend to hold for a longer time (shelf life) compared to the less waxy varieties.

Apart from affecting quality, water loss through dehydration affects sellable weight of produce with losses above 5% identified as a serious loss leading to shrivelling of produce.

Figure 32 Normal beans stored under controlled temperature

Figure 33 Dehydrated pods exposed to high temperature.

Table 8 Rate of perishability

Rate of perishability		
Product	**Perishability index**	**Potential life (shelf-life)**
Broccoli, cauliflower, strawberry, blue berry	Very high	<2week
Avocado, celery, pineapple, fine beans, tomatoes	High	2-4weeks
Lemon, watermelon, potatoes and mango	Moderate	4-8weeks
Onion, apple, garlic, and pear	Low	8-16 weeks
Dried fruits and vegetables, nuts	Very low	16-36 weeks
Frozen vegetables	Extremely low	>52 weeks

4.3 Production Aspects

4.3.1 Crop variety

The quality and potential shelf life of vegetables are partly dependant on genetic control, and can therefore be manipulated by breeding. Plant breeding has improved shelf life, desired shipping qualities, nutritional value and good processing attributes for a number of crops. These factors are important and are needed in developing countries, where refrigeration facilities are expensive and there long distances to be covered before reaching the markets. Due to these, some varieties of crops like avocado can be exported by ship due to longer shelf life, which was not possible earlier.

4.3.2 Climatic factors

4.3.2.1 Temperature

Proper timing of planting, protected cultivation or use of high temperature-resistant varieties can minimize the problems associated with poor quality of produce. Optimum growing temperatures for tropical vegetables such as fine beans range from 20-32°C while for cool season crops (e.g. broccoli) 15.5^{0}C on average.

4.3.2.2 Rainfall

Too much rain towards harvest can result in beans pods being soiled leading to mechanical injuries as a result of abrasion during washing. Washed beans have higher probabilities of decaying during storage and transport. Furthermore, outbreaks of foodborne illnesses have been traced to contamination of produce due to adhering soil particles during rainy periods.

Soil particles carry pathogenic microbes and the harvestable part of the plant (e.g. pods) can be protected by **mulching and trellising**. Sanitary washing after harvest can also minimize the problem. For this process the use of chlorinated potable water is recommended.

4.3.2.3 Light

Too much light intensity may cause sunscald and increased plant temperature, resulting in high temperature-related quality defects. Although in the tropics beans are not commonly planted under the shade, the harvesting of beans should be done when the environment is cooler, hence either in the early morning or in the late evening.

4.3.3 Cultural factors

The use of appropriate best growing practices and techniques results in the production of high quality, safe fresh produce.

4.3.3.1 Seed material

Commercial producers, in consultation with the market, need to ensure procurement of seeds through certified suppliers to ensure optimum yields and resistance to pests and diseases.

4.3.3 2 Irrigation

Most vegetables are composed of 80% water, thus they need adequate supply of water for consistent growth, to yield improved quality and storability of fresh produce. **Drip irrigation** has been found to improve yield and quality of fine beans by reducing losses attributed to soiled pods, aside from increasing water use efficiency, as compared to furrow irrigation. Water source for vegetable production must be restricted with no access to livestock due to increased food safety risk; in general, direct contact with the harvestable part must be avoided.

4.3.3.3 Mineral nutrition

Nutrients are required in appropriate amounts. Excess or deficiency in planting media affects produce quality and shelf life. Excess nitrogen made available for uptake by crop results in poor storage quality and increased susceptibility to physiological disorders.

Concerns of excessive fertilizer usage leading to soil acidity, nitrate contamination of ground water and chemical residues have resulted in an increased use of organic fertilizers. Farmyard manure of animal origin used as organic fertilizer should be deployed with caution as it could pose a food safety microbial hazard.

4.4 Pest Issues-Entomological Considerations (Caterpillars, Thrips, White Flies)

Global concerns on disruption of trade occasioned by likely entry of **insect pests** through food movement has led to the introduction of strict control measures by many trade partners. The EU requires strict controls of phytosanitary measures to prevent the importation of insect pests with several directives issued to control and prevent the entry of insect pests.

A large number of insects attacks on vegetables occur both at pre- and postharvest stages, resulting in economic losses. According to the World Trade Organisation (WTO), about 750,000 insect species are currently known, out of which 450 are considered serious pests.

Insect pests are more destructive at the larva stage leading to massive loss of vegetables. Among them, the white fly (*bamisa tabaci*) is the most important pest in export trade of fine beans. Other insect pests include bean pod borer and moths (e.g. *maruka vitrata*).

Postharvest management of insect pests should involve the use of insect traps, cold sterilisation, high carbon dioxide exposure or irradiation, whenever possible. Chemical control using insecticides should be avoided after harvest and only be done during pre-harvest stages with maximum observation of Pre-Harvest Intervals (PHI) as recommended on the label.

Figure 34 Caterpillar bites on beans

Figure 35 Thrip marks in beans

CHAPTER 5: FINE BEANS HANDLING AND PRODUCT SPECIFICATION

Key highlights of the chapter:

- The chapter equips the reader with techniques on how to differentiate the various grades of beans based on harvest maturity indices;
- The readers are equipped with skills on how to develop a harvest protocol and the harvest requirements during and after harvest.

5.1 Product Handling and Specification

Producers or growers of fruits and vegetables face challenges when deciding if a crop is ready for harvest. It is common practice in fresh produce production that the ideal harvest stage of different types of fruits and vegetables is determined by market requirements as a measure of ideal condition for consumption.

This condition is usually referred to as **horticulture maturity**, as opposed to the botanical description of maturity that reorganises maturity as completion of “active” growth by a plant. Harvest maturity in fresh produce refers to the time when the “fruit” is ready to be harvested, taking into account the time required to reach the market and possible management requirements en- route to the market.

For non-climacteric produce, the harvest stage would require actual market desired specification i.e. chillies and fine beans. Climacteric produce such as banana, avocado and mangos, harvest time will need a time lag (harvest earlier) necessary to ensure produce gets to the market at ideal maturity.

Types of maturities

- Physiological maturity;
- Consumer or horticulture maturity.

5.1.1 Physiological maturity

Refers to the attainment of full development of stages just prior to ripening or seed development in non-climacteric fruits.

5.1.2 Commercial or horticulture maturity

Maturity stage at which growth and development is optimal for a specific use. Horticulture maturityis further classified into three different groups.

Physiological immature

Vegetables are harvested when they are tender, crispy and fibre free such as fine beans, peas, okra and carrots.

Figure 36 Non climacteric vegetables Baby corn, pea, okra, beans and runner beans


Okra


Fine beans


Baby corn


Runner beans

Firm and mature

Fruits and vegetables are harvested when they attain certain characteristics such as shape or size.

Figure 37 Firm and mature climacteric fruits


Bananas


Mango


Passionfruit


Pawpaw

Harvest at ripe

Non-climacteric fruits maturity is referred to as ripe maturity i.e. pples, oranges and pineapples.

Figure 38 Harvest when ripe non-climacteric fruits


Grapes


Citrus


Pineapple


Strawberry

5.2 Determination of Maturity (Maturity Indices)

Maturity is determined based on estimation or individual judgement. Most growers decide when to harvest based on visual examination and samples of produce in the farm a few days before actually harvesting. This form of determination is also referred to as **sensory maturity**, which relies on the judgmental ability of the harvester.

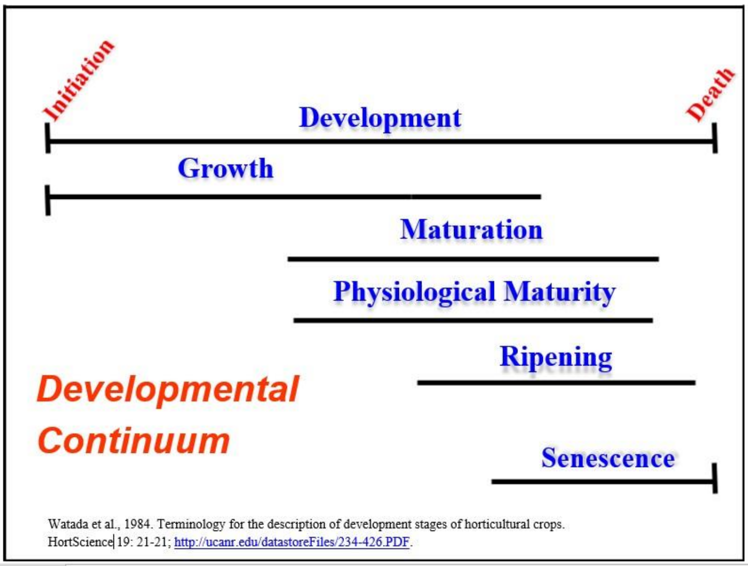
5.2.1 Use of objective and subjective techniques

- Odour or aroma through smell;

- Size, shape and colour through sight;
- Texture, hardness and softness through touch;
- Tapping of fruits hear to sound through resonance;
- Taste as a measure of sweetness, sourness or bitterness.

Adequate experience is the best guide for visual assessment. Harvest maturity can readily be observed in some crops: bulb onions when their green tops collapse and potatoes when the green tops die off. Other crops can be more difficult fine beans specification are close in visual appearance.

Figure 39 Maturity development stages of various fruits and vegetables



Source: Watada et al 1984

5.2.2 Disadvantages of subjective techniques

- Variations in weather may mislead harvesters;
- Variations in biotic and abiotic factors which may (micro climate) influence the crop judgment (plants near pond/compost pit grows luxuriantly);
- In a commercial production (large farms) setting up an area for the estimation of maturity levels of produce becomes tedious, thus some mature pods may be left on the crop leading to losses during next harvest as a result of over maturity.

Other methods of maturity determination include: **computation methods**, **physical methods** and **chemical methods**.

In fine beans production chemical (oil, juice, sugar level) and computation methods of maturity determination are rarely used, while physical methods are important to harvesters and could aid harvesters determine maturity for a crop on border line of maturity and immature phase.

Physical methods

There are a number of physical methods on maturity test for a variety of fruits and vegetables. These include: fruit retention strength, ascetic sound test, skin color changes, aroma, fruit opening, abscission, specific gravity and shape for fruits. For vegetables, physical methods techniques for fine beans include use of size (beans diameter and length), firmness/solidity in cabbages through application of pressure.

Destructive methods

The determination of maturity of pods under the destructive method involves the use of fingers squeeze and touch technique.

Crops such as peas, fine beans and okra are squeezed between fingers (Figure 39) to determine their freshness, which normally correlates with firmness of the harvested pods

Figure 40 Fingers squeeze and touch technique

5.2.3 Maturity indices of fine bean in various markets (UK/EU market requirements).

Fine beans maturity specification is defined by market requirements, however most EU and UK markets categorised beans in the following grades:

1. Extra fine beans
2. Fine beans
3. Bobby beans

Figure 41 Extra fine, Fine bean and Bobby beans specification

5.2.3.1 Characteristics of extra fine beans

The extra fine bean diameter measure between 5mm to 6.5mm diameter, a spec ruler (Figure 40) is used to determine the diameter, however the length may vary depending on the variety.

Extra fine beans are sensitive to temperatures due to underdeveloped cells compared to fine beans thus control of dehydration rate is paramount.

5.2.3.2 Characteristics of Fine beans

Fine beans are the most common in terms of traded volumes in all categories of beans. The description is based on diameter ideally 7mm-8.5mm while the length may vary depending on variety at maturity. However, some varieties produce better post-harvest yields when waste generation is considered. On average a length of 12 (top and tail orders) to 14 cm for prepack standard orders is desirable.

Figure 42 Fine beans graded

Figure 43 Fine beans in crates

5.2.3.3 Characteristics of bobby beans

Demand for bobby beans in the EU and UK market is limited. The main customers are caterers for institutions. Bobby beans are considered over mature beans with a diameter range of 8.5mm to 12mm. Bobby beans have higher fibre levels and can be referred to as being more fibrous and stringy.

Figure 44 Bobby beans specification

Figure 45 Bobby beans in crates

Over maturity of fine beans (bobby) contribute significantly to losses due to limited market options with consumers in EU and UK not favouring them. Therefore, unless there are dedicated orders for this produce. harvesting should be done of either extra fine or fine beans only to reduce losses.

5.3 Fine Beans Acceptable Quality (Sensory Maturity)-Appearance, Consistency and Texture, Crispness, Colour, Flavour and Aroma

Market requirements for specific grades (extra fine, fine and bobby beans) of beans is determined by consumer preferences. There is an extensive study on factors that determine consumer preferences, which includes various sensory properties of the various grade as detailed below. The measure of snapping of fine beans is used to determine freshness of beans in the market with studies indicating a correlation (r=0.67) between snapping (firmness) and sensory properties of texture.

5.3.1 Sensory properties of fine beans

5.3.1.1 Texture

Texture is a very important attribute of food for consumer s. It is a measure of the experience of contact with food and it is defined as the overall feel the food leaves in the mouth after consumption, comprising of properties that can be evaluated by touch. In fine beans, the texture is determined by product cellular organelles, biochemical components, water content and cell wall composition.

Improved texture in snap beans "fine beans" is a product of repetitive genotypic manipulation of bean crop to increase disease resistance while improving the overall texture of the product upon cooking (Pevicharova *et al.,* 2015).

5.3.1.2 Crispness

Crispness is a measure of how easy it is to break a fresh bean pod. The easier it takes to break a bean pod the crispier the beans are. This correlates with the freshness of beans, the fresher the beans the easier the breaking. Snapping sounds tend to change with an increase in storage or shelf life. Usually beans at early harvest stages will snap more than beans that are old in their shelf life.

5.3.1.3 Appearance/colour

All fine beans varieties are green in colour, however the glossiness and intensity of the colour tends to fade with the increase in harvest age. Other factors may change the shade of colour even though beans are not old, and these include exposure to ethylene gas. Fresh beans exposed to ethylene gas turn to a pale yellow colour at day three of shelf life thus affecting the sensory characteristics of produce.

5.3.1.4 Stringiness

Stringiness refers to the amount of fibre present in pods. Fibre content is correlated with age of harvested produce, thus beans tending to bobby grade have more fibre compared to extra fine beans. Trainees should be able to differentiate between texture and stringiness in the practical season. It is also important to note that some varieties of beans have more fibre at same age compared with other varieties. This is an important factor in selection of varieties preferred by the market.

The sense of sight is used to determine how stringy the beans are compared to other samples provided.

5.3.1.5 Aroma and flavour

The normal aroma of fine beans is characterised by greenish teste with no off odour or off flavour. Off odour in beans can result from chemical taint due to the use of perfumed detergents/sanitizers and contaminated containers. The exposure of beans to some crops with strong pungent smell such as onions and hot pepper for long duration (>36hrs) is likely to impact negatively the normal odour of fine beans. Good agricultural practices should be adopted at the farm to ensure no introduction of off odour or off flavours in harvested produce.

5.4 Tools for Quality-Instrumentation (Measure Maturity Indices –Size, Sugar Levels)

In the absence of tools, simple techniques used to measure freshness of product include snapping the beans between the fingers. An immediate snap indicates the beans are fresh and tender, while dehydrated beans will not snap but instead coil and eventually snap with a popping sound.

Tools used to measure maturity indices of fine beans include inexpensive spec rulers that have diameter dimensions measuring 5mm to 12mm (Figure 46).

Through the Vanier calliper Figure 47 measures the brix to determine sucrose levels in beans though not common.

Figure 46 Spec ruler

Figure 47 Vanier calliper

Figure 48 Figure Digital thermometer probe

Figure 49 Scales

5.5 Harvesting Methods and Techniques (Harvesting Procedure)

Harvesting of fine beans is done by hand in developing countries, though mechanization is possible in advanced set ups. Harvesters have to be advised on the appropriate methods of harvesting, including techniques that reduce wastage.

In order to minimise wastage during harvesting, harvest supervisors must sample a block to ensure that beans are within market specifications. Harvesting is recommended in the morning hours when temperatures are lower.

As a rule of the thumb no block should be picked unless there is authorization to pick and it is confirmed by the agronomist or senior manager that the block is clear on all the chemicals applied.

The ultimate goal of a harvest procedure is to ensure that produce of high quality standards with no contamination is delivered to the pack house to process for customers with equal quality utilities.

5.5.1 Components of a harvest procedure

5.5.1.1 Personal hygiene rules to be observed before harvesting:

- No one suffering from contagious diseases such as diarrhoea, vomiting, nausea or open wounds shall be allowed to do picking/harvesting work until he/she is treated. A doctor's certificate should be produced upon reporting back to duty to prove he/she is medically fit and at least 48 hours after their last episode if they had diarrhoea or vomiting. If anyone falls ill while on duty, he should report the matter to the harvest supervisor immediately;
- All hair must be covered with a net or headscarf. The proper personal clothing must be kept clean and worn all the time;
- Nails must be kept clean. No nail vanishes or strong scented perfumes should be worn for those involved in harvesting. No food including **nuts** or reading materials such as newspapers should be taken to the fields being harvested;
- Mobile phones are to be left behind at a dedicated staff items holding facility, to avoid them dropping or breaking while handling produce. Before any harvesting work commences, one should wash his/her hands with potable water. Always clean hands after visiting the toilet. Only odourless soap should be provided and the only one used.

In case of a cut/oil leakage/glass or hard plastic breakage, harvesters are required to report to the supervisor, the area must be condoned off and no harvesting can be done in that area. A search for glass fragments should be done until the whole piece can be accounted for. In case of an oil/diesel leak, the crop must be inspected and contaminated crops must be removed. Any produce harvested from this area must be disposed of due to contamination; the incident should be recorded together with the actions taken.

- The cut(s)/wounds must be covered in a blue plaster. In case the injured person is allowed to continue working, it should be in a different department and should not handle produce directly;
- No smoking is allowed unless they are in designated areas;
- All harvesters must follow the company farm policy on jewellery. Wearing watches, earrings, studs, and other body piercings should not be allowed. Eating should not be allowed in crop growing and harvesting areas

5.5.2 Harvesting crates /approved bags/tabs/knives (containers and tools)

Before use, all tubs and crates must be cleaned. They should be soaked, cleaned with detergent and rinsed off thoroughly with portable water. They must not be placed directly on soil but rather be placed on a spacer crate or a pallet.

Figure 50 Harvested produce kept directly on the ground

Figure 51 Use a spacer crates or clean material to place harvesting crates with products

Crates should not be filled to the brim, to avoid produce damage and give room for air circulation. The grading must be done in the field and various grades must be separated into different crates. Knives should be sharp to avoid crop injury and stored overnight in a disinfectant for hygiene to avoid cross contamination.

Figure 52 Recommended filled crate < 16kg

Figure 53 Wrongly filled crate (overfilled crate) >20kg

Harvested produce should not be kept in direct sunshine; additionally the harvested produce should be kept into the charcoal coolers stacked on pallets awaiting transport into the pack house.

Figure 54 Use some form of cover to control heat/sun from getting to harvested produce

Figure 55 Do not place harvested produce direct in sunlight

At the end of the day all crates/tabs must be collected from the fields, cleaned and stored at crate washing areas to avoid any bird droppings contamination, rodents and insects ready for the next day's work.

Never place knives or other harvesting tools in the soil when they are not in use.

5.5.2.1 Muddy produce

Muddy produce from the fields should be pre-washed if possible with chlorinated water as instructed and calibrated by the pack-house personnel.

5.5.3 Type of equipment and their conditions prior and after harvesting.

Several equipment types are used during harvesting and after harvesting, specifically designed to reduce wastage, contamination and keep produce cool longer and worker occupation safety. Some of the equipment include:

- Harvesting bags;
- Crates;
- Pallets or spacer crates;
- Potable water holding facility for hand wash.

All equipment used during harvesting must be cleaned and repaired before use, equipment must be checked and if they are of sound status a control to identify the potential introduction of physical contaminants in produce should be run.

Harvesting equipment such as crates must be checked for cracks and any repairs done must be effective and not put the produce at risk of contamination. Wooden containers are not fit for storage due to risks associated with wood splinters (foreign body contaminants).

Figure 56 Picture of damaged crates repaired at the corner

Figure 57 Use of alternative packaging. Jumbo crate suitable for chillies transport due to challenges in cooling fine beans

Figure 58 Clean standard crate suitable for harvesting fine beans

Figure 59 Dirty crates should not be used during harvesting

Storage of cleaned harvest equipment when not in use must be in an enclosed place away from birds and rats particularly overnight and over the weekend. Checks for potential faecal contamination from rodent and birds prior to use are needed.

5.5.3.1 Infrastructure requirements necessary during harvesting

Harvested produce must be immediately stored in a cool place. At farm level, farmers should build shades from inexpensive materials and temporally store produce awaiting transfer to grading and sorting pack houses.

Among the necessary infrastructure one can find:

- Zero-energy cooling units;
- Produce collection sheds;
- Hand wash stations.

When transporting produce from harvest blocks to sheds, it is advisable to ensure smooth access roads/paths to the block to minimise wastage due to spillage, mechanical damages due to abrasion of produce as a result of vibration.

Figure 60 Charcoal cooling unit

Figure 61 Not ideal grading shade

Figure 62 Improved field grading shade

5.5.4 Cold chain management after harvesting

Cooling is considered an important post-harvest step in handling of produce as reducing temperature of harvested product greatly reduces physiological functions, such as respiration, ensuring shelf life elongation, and it protects produce quality, while reduce volume loss through water loss and decay.

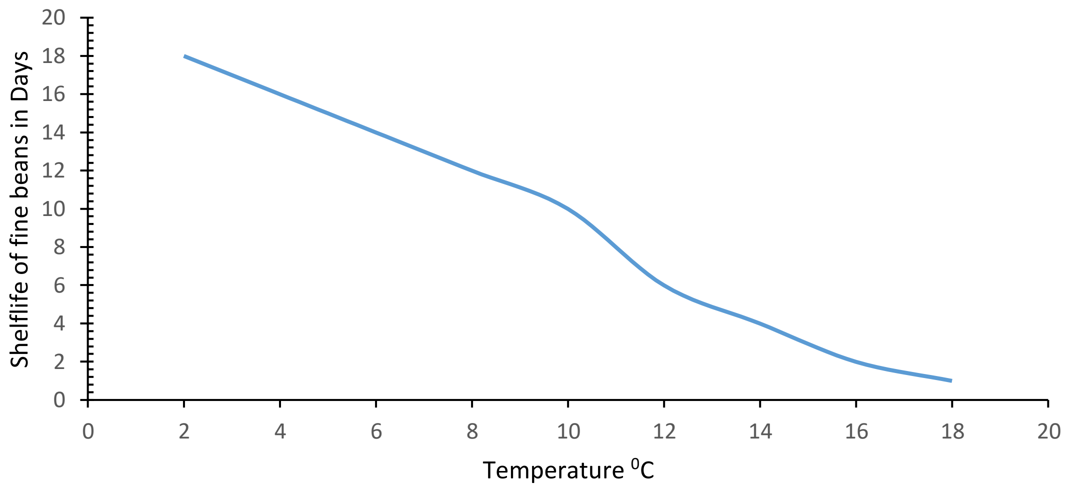
Pre-cooling systems include room or slow cooling, forced air-cooling, hydro-cooling, vacuum air-cooling and contact-cooling using ice or dry Ice.

Temperature management is a very important aspect in control of quality of fine beans after harvesting. Product temperature is approximately 3°C degrees higher than environmental temperature and it keeps rising as long as no actions are taken. This leads to the deterioration of quality of produce, reduction of shelf life, multiplication of microorganisms and loss of weight.

Simple techniques can be used to lower the temperature of produce, and it is recommended to use the cobalt technique, zero energy units or simple sheds made of insulation materials to avoid exposure of produce to direct sunlight.

Figure 63 shows the effects of temperature on estimated shelf life of fine beans, the beans have a higher shelf life when temperatures are maintained low (4-8 °C), while shelf life is reduced to one day with increase in temperatures above 18 °C.

Figure 63 Graph of effect of temperature on shelf life of fine beans



5.5.5 Washing of fine beans during wet seasons

Fine beans to be packed as standard and prep-pack should be washed as a last resort, in the event they are exposed to excessive soil during harvest. The washing of beans increases losses due to abrasion as a result of rubbing off soil from bean pods. It is advisable to engage other controls such as varying harvesting time after rainfall/overhead irrigation to allow reduction of moisture /attachment of soil on bean pods.

Portable water must be used once a decision to wash beans is made. An appropriate food based disinfectant at recommended dosage should be used to reduce microbial contamination. Some of the common microbes to be targeted include white moulds, anthracnose and rots.

5.5.6 Product losses reduction strategies and technique

Routinely harvest mature pods to reduce number of overgrown pods

Fine beans varieties are first growing crops with an average increase of 0.1 cm in length every one hour at optimal growth conditions. With such high growth rate, frequent harvest is required to ensure beans are harvested in line with customer specifications. This will minimize losses attributed to poor quality due to overgrown pods. Thorough supervision during harvesting is necessary to ensure no mature pods are left on the crop.

Ensuring the use of hygienic (cleaned and sanitized) harvesting equipment is needed to prevent spreading of diseases

Harvesting equipment can be a vector of disease spread within a consignment. Producers should ensure all equipment used for harvesting is cleaned and sanitized after use. Harvesting equipment must be stored in an enclosed and secure environment overnight to minimize potential contamination through birds and rodents faecal matter.

Avoid over handling and rough handling of the produce

Considering the delicate nature of fine beans, the reduction in number of handling steps is critical to prolong shelf life, reduce losses and increase yields. Only absolute necessary steps should be performed. Most losses occur in the pack house due to multiple handlings, in cases where produce have mixed grades in the same crates, supplied from the fields. It is therefore necessary to isolate the three grades of fine beans during harvesting to minimize multiple handling during sorting and grading.

Fine beans should be handled with care. Management should provide equipment that is fit for purpose to ease movement of produce both at farm and grading shades. These include crates, trolleys, crates, boxes and so on.

Produce holding crates should not be packed too tightly restricting air flow

As discussed in this chapter, compression damage is usually unseen, however the effect is felt during grading where a considerable amount of are beans is graded out as rejects or grade 2. Tightly packed, overfilled crates and use of jumbo crates (Figure 57) do not allow air circulation within fine beans creating a conducive environment for anaerobic bacteria to thrive leading to rots on any damaged or injured produce.

Select for harvest only mature pods, leaving immature pods for the next harvest

Immature pods tend to dehydrate faster compared to moderate and fully matured pods. Most immature (< 6mm diameter) beans are graded out and rejected since they do not meet the customer specifications. The pods have less weight thus decrease the production expectation in a block which usually would be 15T/ha. Adequate training is needed for the harvesting team on harvest specification.

Target and plan harvesting in the morning after all moisture has evaporated from the plants

One of the main causes of losses is foreign matter attachment on pods, usually soil, in the form of mud leading to requirement to wash the produce. Washed beans have a lower yield per lot compared to unwashed beans. Rots develop more on washed beans due to an increase in moisture (abiotic factor) suitable for the growth of microbes. It is therefore recommended to harvest fine beans in mid-morning, when all moisture on bean has evaporated minimizing the need to wash.

Harvested produce should be quickly removed from the sun after harvesting

Fine beans plucked from the mother plant start to wilt or dehydrate immediately, due to the physiological processes discussed in Chapter 4. To delay the processes of respiration and transpiration, fine beans should be kept in a cool environment immediately after harvest, where temperature of 12-10^{0}C is recommended. Building of harvest sheds is recommended as close as possible to the blocks with access to clear roads to facilitate collection and transportation to the zero energy cooling units/packing shade.

Grading should be done to remove diseased, damaged and defective beans

One of the leading factors contributing to post-harvest losses is the presence of diseases in harvested beans. Most bacterial, fungal and parasitic organism have the ability to withstand low temperatures, especially when in spore form. To reduce progressive development of diseases within the value chain diseased, damaged and defective pods need to be removed from harvested produce as soon as possible. The most damaging microbes include anthracnose (*Colletotrichum lindemuthianium*) and grey and white moulds (*Sclerotinia sclerotiorum*).

Planning transitions between different weather conditions

Fine beans are grown all year round in Rwanda both as rain fed or under irrigation. During dry season, the change in climatic conditions between rainy season and dry season can lead to losses. Farmers are advised to apply preventive propyletic sprays (Switch, Luna sensation etc.) on fine beans crops, between the dry and onset of rainy season. Other cultural activities, such as preparation of drainage system would help reduce flooding in fine beans blocks.

CHAPTER 6: HORTICULTURE PRODUCE STORAGE

Key highlights of the chapter:

- The readers are equipped with skills on various storage requirements in a fresh produce handling set up, the various types of storage facilities and likely impacts on quality in cases of non-compliance to the requirements**;**
- The cost and benefits of improved storage facilities.

6.1 Produce Storage

Storage of harvested fine beans is critical in the obtainment of desired market quality. Efforts must be made to ensure conditions of storage are appropriate and do not contribute to further degradation of produce. Generally, **the temperature, ethylene and humidity of air around the product are the major factors** which contribute to maintenance of product quality throughout its entire shelf life.

The reasons for the storage of fine beans in refrigeration:

- For preservation;
- For maintaining nutritional quality;
- For reduction of losses due to wastage;
- For availability of produce for consumption and processing based on market based on market demand;
- For an increased shelf life.

Fine beans stored under optimum temperature of 5-7^{0}C and relative humidity conditions of (70%-80% relative humidity) will extend the shelf life to the maximum of between 12-14 days. Maximum care is required to ensure concentrations of gases such as oxygen, carbon dioxide, and ethylene in the storage atmosphere are within acceptable range of 2-3% and 5-6%. To maintain the shelf life of the product, it is advisable to avoid mixing fine beans with other crops that emit huge amounts of ethylene such as bananas, passion fruits, chillies, avocado and tomatoes.

Certain combinations of products during storage can stimulate change of colour of harvested beans leading to discoloration. Segregation of products is imperative to reduce the discoloration of fine beans.

Due to market forces, fine beans will be stored and depending on market, sales movement will take place when the product is required thus a properly designed storage place that meet set conditions is required (store) to protect beans from adverse conditions, or while it is awaiting sale.

6.1.1 Important factors that influence storage of fresh produce

- Maturity of produce at harvest;
- Harvest practices;
- Pre-harvest factors;
- Hygiene and sanitation of the storage unit;
- Pre-storage treatments;
- Temperature settings;
- Relative humidity of the storage environment.

Temperature and relative humidity are the most important components in a storage set-up with variation in setting depending on the specific product, as they are important to enhance its shelf life.

There are various low cost technologies used for the storage of other produce:

- Traditional and low cost technology in form of clamp storage for root and tuber crops, bulk storage for dried bulb crops, sand - coir and in- situ/on site/natural or field storage;
- Zero energy charcoal cooling units: involving the use of locally available cheaper material in construction of structures at farm level that can be used to store produce over night at lower temperatures thus ensuring shelf life of produce is not affected.

Table 9: Fine beans ideal storage requirements at various value chain stages

Fine beans point of storage	**Facility requirements**					
	Humidity RH%	**Temperature ⁰C**	**Ethylene**	**Reason for storage**	**Maintenance requirements**	**Responsibility**
Harvesting sheds	70	12-15⁰C	Nil	Await transport to grading shed	Minimal	Farmer
Zero energy units	75	9-12⁰C	Nil	Awaiting exporter to pick	Minimal	Farmer
Grading shed	75	10⁰C	Nil	Awaiting transport	Moderate	Farmer
Pack house cold rooms	80	5-7⁰C	Nil	Market demand, freight availability	High	Exporter

6.1.2 Good practices during farm storage of harvested products

The harvest temperature of fruits and vegetables is normally very close to ambient air temperature in the tropics, ranging between 25-30°C but may vary depending on weather conditions. In some instances, the temperature may be as high as 38°C. At such high temperature the respiration rate of the product is usually extremely high. **The higher the rate of respiration (higher storage temperature), the shorter the postharvest life of the commodity,** unless immediate controls are in place**.** It is often recommended to harvest early in the morning to take advantage of lower prevailing temperatures unless the crop is still wet due to rain.

Even though early morning harvesting of fine beans or late evening is recommended, this may not be feasible or the temperature may not be as low as desired. Thus, the produce would need rapid cooling of harvested produce through forced air cooling (pre-cooling) to the recommended storage temperature, which prolongs postharvest life while maintaining the quality of harvested beans.

Pre-cooling (Figure 64) assists in prolonging shelf life of highly perishable produce such as fine beans, leafy vegetables and sensitive fruits such as strawberry.

Due to the high cost of energy, operation costs for cold storage facilities remain high, resulting in their abandonment while in some areas accessibility to the national grid remains a challenge due to the installation costs.

The current trend has been to research alternative low cost facilities, capable of reducing temperature of harvested produce overnight before collection by exporters such alternatives include zero energy units, cobalt technology and use of solar powered cold chambers.

Figure 64 Modern pre-cool cold storage

Figure 65 Modern cold room storage

Figure 66 Pre-cool air circulation mechanism

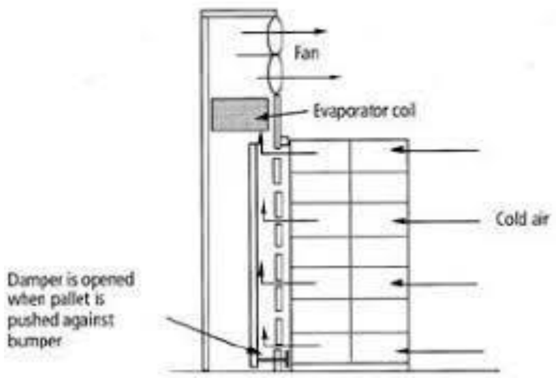


Figure 67 Open truck arrival temp (18.90C) of fine beans to pack house

6.1.2.1 Temperature management during storage

Currently, in Rwanda there are facilities across the country installed by the government. However, they remain inadequate since horticulture producers are dispersed across the country.

The structures are in the form of collecting centres, grading sheds with one modern pack house and airport cooling facility. Cooperative-owned facilities or marshland development have facilities such as zero energy units, grading sheds and satellite packing houses.

To facilitate cooling, the cold room should be arranged leaving enough space along the walls to allow proper circulation. Warm products should be kept on the furthest wall opposite the cooling funs to allow faster cooling.

Always keep produce off the floor, use of plastic pallets or empty spacer dedicated crates is recommended (Figure 68 red empty crate at the bottom).

Figure 68 Properly spaced raw materials in crates (10cm space) along the cold room walls

Figure 69 Improperly spaced crates in cold storage, no space between the walls for air circulation

6.1.2.2 Effectiveness of the system for removing field heat and extending shelf life:

Removal of field heat is critical in ensuring harvested fine beans meet desired shelf life and quality requirements through slowing physiological processes that contribute to senesces such as respiration and transpiration. Effective removal of field heat is mainly achieved through the use of pre-coolers (forced air mechanism) in the shortest time possible. Slow cooling is an alternative, however efficiency and results are likely not to be appropriate especially where large volumes of produce is involved.

6.2 Analysis of Cool-Chain

Current cold chain infrastructure is inadequate, especially between the farm to the pack house.

At the farm level, there is inadequate field cold storage facilities, logistics between the farm and pack house are done by use of open trucks thus unable to maintain storage temperature of produce.

6.2.1 Costs and benefits of operating each cooling system

The initial costs of installation of necessary cold room machinery remain high, although the benefits in control of quality and minimization or reduction of post-harvest losses are far more beneficial in the long term.

The demand for cooling systems is very high among exporters as there are very few exporters with capacity to install such high cost structures. 90% of current exporters of fresh produce utilize government subsidized cooling systems in the pack house and airport.

6.2.1.1 Compatibility, segregation and traceability requirements during storage

Fine beans are compatible with many other leafy vegetables and can be mixed in the same storage facility. However, care must be taken to avoid mixing high ethylene producing fruits with fine beans for a long duration of time. Flowers should not be mixed with beans at all.

During storage, segregation is important to ensure that produce is not mixed up. In particular, extra fine bean and fine beans are mainly different in specification and must be segregated and marked clearly. This may be done through colour coding or usage of tags that are different in colour.

Traceability

Each stack of crate must be tagged with product identification/or trace ability code. Whenever possible, crate tag identification is preferred as it guarantees identification to the smallest unit possible from the farm.

6.2.1.2 Product weighing – Equipment requirements weights and measurement

All produce coming from the field must be weighed and inspected for respective grade and individual weight. These shall be recorded to gauge picker performance and understand quality requirements.

CHAPTER 7: HORTICTULTURE PRODUCTS TRANSPORTATION

Key highlights

The readers are equipped with knowledge on the effects and impacts of the various transport modes currently in use along the fine beans value chain.

7.1 Fine Beans Transportation

For fresh produce to be available to consumers, it must reach the diverse markets on a timely basis in acceptable quality. As produce (fine beans) is moved through the food systems, it may be transported by humans, animals, airplanes, boats, or on ground vehicles. In developing countries produce is transported many times and by different methods from remote rural smallholder farms, to collection sheds along the major highways, to the processing facilities en-route to the airport for own ward transportation to the EU and UK markets.

Every time produce is transported from one point to another it is handled, delayed, vibrated, placed under pressure, and subjected to a variety of conditions which are likely to impact negatively on the quality of the produce leading to some degree of losses before it gets to the market.

7.1.1 Industry requirements on mode, form and type of transportation of perishable products

There are various compliant forms of transportation of produce from farm to pack house through to the airport. The preferred mode is with trucks with refrigeration capacity that are capable of maintaining temperature of the consignment.

Figure 70 Modified TukTuk for produce ferrying within the farm

Within the farm, transport of fine beans or other commodities can be facilitated by the use of covered trolleys or tractor trailers. In case a farm is well mechanised simplified three wheel tuktuks can also be used (Figure 70). Trucks used for product transportation should not be used for waste transportation due to risks of microbial cross contamination.

7.1.1.2 Temperature management during transport

At the farm level it may not be possible to measure the temperature of produce during transport. However, in case there are no refrigerated trucks and a non-refrigerated closed truck is used for transportation, it is important to always open the truck for a few minutes before loading fresh produce to allow cool air circulation.

Non-refrigerated trucks should have ventilation systems large enough to allow circulation but positioned strategically to limit the entry of dust into produce while transporting produce to the pack house, as shown in

Figure 72, completely open truck should be discouraged since they fall short of and food defence requirements Figure 73.

Figure 71 Adequately secured but closed truck and not temperature controlled

Figure 72 Open truck with no controls on food defence and food fraud requirements, risk of dust contamination

Figure 73 Ideal truck for transport of raw materials, sorted and packed products

Transportation in refrigerated trucks should have temperature set at 5-8 °C of the refrigeration unit.

7.1.1.3 Product hygiene and sanitation requirements

Produce hygiene and sanitation are critical to safe fine beans. The following requirements must be observed during farm transport of produce to pack houses:

- The turn-boys handling the produce must observe the picking hygiene requirement;
- The truck should be in good repair with no oil leaks;
- The truck should be cleaned on a daily basis;
- Personnel handling produce must be provided with protective clothing, including: overcoats, head gear and gloves.

7.1.1.4 Stalking and segregation during loading and offloading

- The crates should be placed on pallets or spacer crate while loading in the truck;
- The truck body must be free from dust and produce must be covered with a moist hessian cloth to keep produce on transit cool;
- The produce must be handled with care at loading, transit and offloading.

7.1.1.5 Transport equipment

Offloading and loading equipment should be available and maintained at all time, and it must be adequate for loading and offloading within the shortest time possible. The loading and offloading ramps should be such as to enable truck offloading and loading be carried out efficiently. Gas folk lifts are not ideal since they emit heat contributing to the increase in temperature in the cold rooms

Figure 74 Truck offloading trolley

Figure 75 Electrical forklift

7.1.1.6 Documentation and records

Documents and records include delivery notes detailing traceability information (block, weight, farm and date of harvest), truck service records, truck cleaning records and temperature records and data logger records for advanced temperature monitoring equipment.

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