MARKUP
EU-EAC MARKET ACCESS UPGRADE PROGRAMME

STUDY

AVOCADO POST-HARVEST MANAGEMENT PRACTICES IN RWANDA

Co-funded by the European Union

East African Community

International Trade Centre

About the handbook

The handbook covers post-harvest management practices and losses reduction strategies for Avocado *(Persea americana*) producers and exporters from the point of harvest, storage, transportation and processing. The handbook highlights simple low-cost innovations and the best practices that can be adopted by producers, exporters and packers of avocados across the value chain, with the ultimate aim to skill-up professionals so as to increase their trade competitiveness in international and regional markets.

The avocado fruit is selected due to its high export potential. Currently in Rwanda, avocadoes make up 30% of all horticultural exports to the European Union and the United Kingdom. To support producers and exporters that are looking to increase exports to desired market destinations, this handbook outlines the practical guidelines and solutions that firms can integrate in their operations as to improve post-harvest management efficiencies and enhance product quality to meet import and buyer requirements of EU and UK markets

Target audience: Small and Medium Enterprises (SME) exporting avocados to the European Union (EU) and United Kingdom (UK). The handbook is designed and presented in simple English as to ensure maximum understanding of the main concepts of post-harvest management practices and quality assurance.

Disclaimer

Acknowledgements

I would like to thank the CEO Mr. BIZIMANA J. Claude, COO Mrs. Sandrine URUJENI, CFO Mr Andre NDIKUMANA and the entire NAEB team for according ITC consultant an environment that facilitated the assessment and drafting of this post- harvest manual. Special appreciation goes to Mr. MUNYANEZA Jean Marie Vianney the Division Manager Emerging commodities for his insights on the evolution of horticulture in Rwanda, Mr. MUGABUSHAKA Norbert, Mrs. INGABIRE Gisele, Mr. NSEKANABANGA Fabien for sharing their knowledge on various post-harvest value addition techniques and Eng. Eric RUGANINTWALI the Division manager in charge of Quality Assurance and Regulatory functions of NAEB for sharing the journey on QMS certification at NAEB and future endeavours in the horticulture sector. Additional support came in from the horticulture exporters who provided critical information on gaps in handling avocados at their various farms identified during various farm and post-harvest handling sites.

Table of Contents

About the handbook ..... **ii**
Acknowledgements ..... **iii**
Acronyms ..... **ix**
Executive Summary ..... **x**
CHAPTER ONE **7**
Introduction **7**
1.1 Scope and content 7
1.1.1 Avocado varieties and characteristics 8
CHAPTER TWO **10**
Factors Contributing to Deterioration of Avocado Quality after Harvesting **10**
2.1 Abiotic 10
2.2 Environmental factors 12
2.3 Biotic factors 12
2.4 Physiological factors (respiration, transpiration, Biochemical-Ethylene emission) 13
2.4.4 14
2.4.5 14
2.5 Pest Issues-Entomological considerations 15
CHAPTER THREE **16**
Common Avocado Post Harvest Defects **16**
3.1 Avocado quality 16
3.1.1 Fruit softness 16
3.2. External fruit defects 17
3.3 Internal fruit defects 21
CHAPTER FOUR **26**
Avocado Handling and Product Specification **26**
4.1 Product handling and specification 26
4.1.1 Types of maturities 26
4.1.2 Physiological maturity 26
4.1.3 Commercial maturity: 27
4.2 Determination of Avocado maturity (Maturity indices) 27
4.2.1. Use of objective and subjective techniques 27
4.2.2 Disadvantages of subjective techniques in avocado industry. 28
4.3 Sensory palatability properties 28
4.4 Tools for appropriate Quality determination -Instrumentation 28
CHAPTER FIVE Avocado Harvesting **30**

5.1 Harvesting activity.....30
5.2 Harvesting fruits at correct maturity levels have the biggest impact on quality.....30
5.3 Avocado Picking by proper Field Handling.....30
5.4 Fruit sizes 31
5.5 Harvesting tools: Crates /approved bags/Tabs/Knives, picking poles and ladder (containers and tools) 31
5.6 Harvesting Methods and time protocol sample 32
5.7 Infrastructure requirements required during harvesting. 34
5.8 Cold chain management after harvesting.....34
5.9 Washing of Avocados.....35
5.10 Avocado losses reduction strategies and technique 35
CHAPTER SIX.....36
Avocado Storage 36
6.1 Produce storage 36
6.1.1 Factors that influence storage duration of avocados produce:.....36
6.2 Good practices during farm storage of harvested products.....37
6.3 Temperature management during storage 37
6.4 Segregation and traceability requirements during storage.....38
6.5 Product weighing 38
CHAPTER SEVEN 39
Avocado Transport.....39
7.1 Avocados transportation 39
7.2 Industry requirements on mode, form and type of transportation of perishable products.....39
7.3 Temperature management during transport (inter farm and airport transfer).....39
7.4 Long distance transport 40
7.5 Product hygiene and sanitation requirements 41
7.6 Stacking and segregation during loading and offloading.....41
7.7 Transport equipment 42
7.8 Documentation and records. 42
References 43
Annex 1:.....44
Oil content and dry matter determination standard procedure 44
Annex 2:.....46
OVEN METHOD (Oil-Plus-Water Constant Method).....46

List of figures

Figure 1: Avocado for export value chain/Value chain segments (steps) for exportable avocado 7
Figure 2: Hass avocado 8
Figure 3: Fuerte avocado 8
Figure 4: Ettinger avocado 8
Figure 5: Harvested Avocados in crates but over filled – damage to fruits will result from stacking crates above 11
Figure 6: Properly packed avocado box - avocado protected from damage 11
Figure 7: Internal fruit damage due to compression damage 11
Figure 8: Bad practice of avocados transport in open truck causing condensation and compression damage to fruits at base of the pick-up truck 11
Figure 9: Properly filled avocado in medium crate 11
Figure 10: Large crates can be used but not filled to the top to avoid compression damage 11
Figure 11: White or grey moulds (Sclerotinia sclerotium) on Avocados 13
Figure 12: Anthracnose on avocados 13
Figure 13: Effects of ethylene on stored avocados 14
Figure 14: Avocado ripening at storage stage due to exposure to uncontrolled ethylene emissions leading to ripening during storage before packing 14
Figure 15: penetrometer used to measure softness of fruits 17
Figure 16: Yellow patch/sunburn on side facing the sun 17
Figure 17: Extensive sunburn appearing as brown patch: 17
Figure 18: Lenticel damage on Hass Fruit 18
Figure 19: Lenticel damage dark spots on Fuerte fruit 18
Figure 20: Chill injury source: 18
Figure: 21 Scarring caused by thrips Scirtothrips perseae 19
Figure 22: Scarring caused by limb rubbing 19
Figure 23: Whitish chemical deposits at the base of fruit 20
Figure 24: Folds on skin surface 20
Figure 25: Folds on skin surface when same fruit is ripe 20
Figure 26: Damages on ripe avocado flesh on fruit with ridges image 20
Figure 27: Fruit appearance before dispatch, some fruits are dull green (more mature) and some shiny (immature) in the same box. 21
Figure 28: Checkerboard ripening observed during ripening process. Image: 21
Figure 29: Rodent damage on stored avocado fruits 21
Figure 30: Grey pulp disorder 22
Figure 31: Ripe fruit with grey pulp disorder. 22
Figure 32: Pedicel attachment starts to rot 22
Figure 33: Stem attachment area rots Image 22
Figure 34: Flesh adherence to seed Image 23
Figure 35: Seed with flesh adherence Image: 23
Figure 36: Diffuse flesh discolouration Image 23
Figure 37: vascular browning image 24
Figure 38: Stem end rot and vascular browning in ripe fruit 24
Figure 39: Surface damage on fruit due to poor harvesting methods (Fruit drop) 25
Figure 40: Internal injury due to poor handling. 25

Figure 41: Stone in flesh on skin 25
Figure 42: Mark of stone flesh detached 25
Figure 43: Avocado grading and sorting machine: 26
Figure 44: Hass avocado ripening changes 27
Figure 45: Microwave for dry matter analysis of fruit samples 29
Figure 46: Weigh scale for sample weighing 29
Figure 47: Beaker for sample preparation 29
Figure 48: Petri dish for heating samples in microwave 29
Figure 49: Penetrometer: for measuring fruit softness 29
Figure 50: Chopping board and knife for sample preparation 29
Figure 51: Secateurs for cutting fruit pedicel 29
Figure 52: NIR Dry matter analyser 29
Figure 53: Moisture analyser 29
Figure 54: Proper in-field collection of harvested avocado- fruits In crates with base crate prevented from direct ground contact 31
Figure 55: In-field transporting of avocados best done in crates. 31
Figure 56: Heaping of harvested avocados without crates is bad practice. 31
Figure 57: Heaping of harvested avocados without crates is bad practice 31
Figure 58: storing and transporting avocados in bags is not recommended 32
Figure 59: properly stacked avocado fruits 32
Figure 60: Hand snap method (only for fruits near the ground) Image: 32
Figure 61: Harvesting picking pole attached with bag to prevent fruit drop 32
Figure 62: Avocado harvest clippers 32
Figure 64: Dirty crates should not be used 33
Figure 63: Damaged crates should not be used image: 33
Figure 65: Clean standard crate for transporting avocados (appropriate fill at the handle slot level) image 33
Figure 66: Charcoal cooling unit 34
Figure 67 : Poor grading site: likely soil and pathogen contamination of product and poor air circulation on heaped product 34
Figure 68: Modern pre-cool cold storage. 37
Figure 69: innovative zero energy cold storage for fruits in farms 37
Figure 70: Truck loading in a dock shelter Image 39
Figure 71: Farm non-refrigerated transport truck 40
Figure 72: short distance pack house to airport refrigerated truck 40
Figure 73: Poor handling of avocados during transportation 40
Figure 74: Neatly stacked, packed avocado 41
Figure 75: treated pallets (legal equipment) 41
Figure 76: Fork lift loading 41
Figure 77: 40ft container loaded for sea transhipment 41
Figure 78: Signage for loading area - non compatible products 42
Figure 79: Truck offloading trolley 42
Figure 80: bulk loading of palletized skids 42

List of tables

Table 1 Key characteristics of common cultivars grown in Rwanda for export
Table 2 Perishability index of various horticulture fruits
Table 3 Fruit softness categorization
Table 4 Correlation of Fruit size with weight of fruits
Table 5 Avocados ideal storage requirements at various value chain stages

Acronyms

BOPP	Biaxially Oriented Polypropylene
BRCGS	Brand recognition through compliance global standard
EAC	East African Community
ETI	Ethical Trade Initiative
EU	European Union
FAO	Food and Agriculture Organization
GAP	Good Agriculture Practices
GHP	Good Hygiene Practices
GLOBAL GAP	Global Good Agriculture Practices
GSFI	Global Food Safety Initiative
HAB	Hass Avocado Board
HACCP	Hazard Analysis Critical Control Points
ITC	International Trade Center
MARKUP	Market Access Upgrade Programme
MRL	Maximum Residue Limit
MSDS	Material Safety Data Sheet
NAEB	National Agricultural Export Development Board
NIR	Near Infra-Red
PPE	Personnel Protective Equipments
PVS	Private Voluntary Standards
RS-HACCP	Rwanda Standard-Hazard Analysis Critical Control Point
SDG	Sustainable Development Goals
SME	Small Medium Enterprises
SNV	Netherlands Development Organization
UAE	United Arab Emirates
UK	United Kingdom
USD	United States Dollar
WHO	World health organization of United Nations

Executive Summary

Horticulture Small and Medium Enterprises (SMEs) in Rwanda face a myriad of challenges in post-harvest handling activities, planning stages of harvest on the farm, in storage, transportation, and processing on factory sites. The main challenges in post-harvest handling are often in the realm of product damages that lead to product waste and decreased profit margins. While various market-related factors play into the loss of export competitiveness, the challenges faced by SMEs in post-harvest handling can be resolved with strategic knowledge that improve quality management of avocados as to diminish product losses and waste.

This handbook offers SMEs an opportunity to improve post-harvest management by identifying:

1. Common factors to the deterioration of avocado quality;
2. Post-harvest defects;
3. Avocado handling and product specifications;
4. Industry requirements associated with avocado harvesting, storage and transport and;
5. Managerial protocols and practical tools that can be used during post-harvest handling.

The Rwandan avocado industry has a great potential to increase their market share in the EU and UK and other international markets, as the country's export value for leguminous fresh vegetables captures a steady incline from 2014 to 2019 at an increase of 4,520,000 USD to 39,640,000 USD[1]. While only a portion of this increase is attributable to the avocado subsector, exporters can infer the opportunities that exist. Improving post-harvest handling practices is one step in right direction that can directly impact export volumes.

[1] FAO STAT. http://www.fao.org/faostat/en/?#data/TP. 22 February 2021.

CHAPTER ONE

Introduction

1.1 Scope and content

The handbook addresses post-harvest management practices and losses reduction strategies for producers and exporters of avocados from harvest, storage and transportation to processing sites. The handbook highlights simple low-cost innovations and the adoption of best practices by producers, exporters and packers of avocados handling across the value chain.

Target organisations: Small and Medium Enterprises (SME) exporting avocados to European Union (EU) and United Kingdom (UK) and other potential countries

Fruit covered: Avocado (*Persea americana*) is a tropical fruit crop with many cultivars that include Hass, Fuerte, Enttinger and Pinkerton varieties produced in Rwanda and shipped to various international markets, the avocado fruit has been selected due to the increase in fruit demand across the globe, therefore an important strategic crop in increasing competitiveness in the Rwanda horticulture sector. It is currently traded at 26% by volume ofall products exported by SMEs to various international markets, placing itsecond to French beans, with projections of increasing demand from theEU and Middle East markets.

However, Rwanda avocado exporters currently experience post-harvest losses at a considerable rate, which is estimated at 40 % of production yield (NAEB 2018 report). The main reason is quality defects, which leads to a significant amount of avocados being sold to the local market as second grade. Due to the absence of value addition mechanisms such as oil extraction, ready- to-eat processing facilities, among other reasons, the rate of exports that are internationally bound is low.

To maximise returns for growers, exporters and shippers of avocado fruit need to reach the consumer with both external and internal quality within product specifications and handling protocols along the value chain. These are key aspects in maintaining satisfactory quality within tolerance limits set out by respective buyers and consumers.

Because each handler within the value chain has an important function whose actions may impact the overall quality of fruits; correct procedures and actions taken during handling also potentially increase the shelf life of fruits and thereby impact the economic viability of the business.

Temperature also remains a main critical parameter in the avocado supply chain, therefore quality of fruits is dependent on equipment functionality, staff actions, conditions of fruits prior to harvest, and handling aspect.

The handbook illustrates activities and protocols and management activities necessary at every step of the post-harvest value chain to maintain fruit quality. A typical handling value chain of avocado will involve the following step s schematically illustrated in Figure 1.

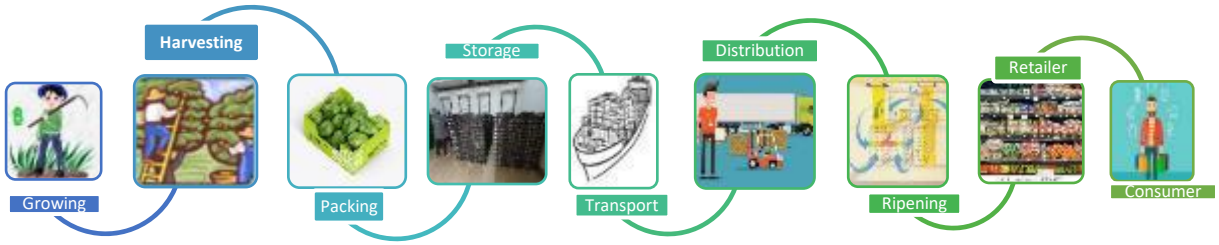


Figure 1: Avocado for export value chain/Value chain segments (steps) for exportable avocado

A quality management system is important in ensuring quality and safety of product is an integral part of daily management operations. It is important that all parts of the supply chain (Figure 1) go through sessions of awareness on potential factors that are likely to lower the quality of harvested products.

Communication and feedback information on quality in the value chain is important with critical specifications shared for each step to ensure fruits are handled in accordance to protocol and specifications. Management of producing facilities need to have a plan on how to handle deviations should protocols not function according to the set-out protocols such as transport, ripening, cold chain storage, harvesting, hygiene protocols.

Operational staff require training on the importance of their activities in relation to maintaining the desired product and quality specifications. An understanding by staff on the avocado fruit, especially on the delicate and complex activities such as packing, shipping, marketing to different customers with diverse requirement is key in realization of a successful business venture.

1.1.1 Avocado varieties and characteristics

There are several avocado varieties produced for export markets however EU/UK and Middle East markets prefer the Fuerte and Hass varieties, this manual has limited its scope to the Hass and Fuerte cultivars due to its higher market demand compared to other varieties produced in the region

Figure 1: Hass avocado[2]

Figure 2: Fuerte avocado[3]

Figure 3: Ettinger avocado[4]

Table 1 Key characteristics of common cultivars grown in Rwanda for export

Characteristics	Hass	Fuerte	Ettinger
Origin	Guatemalan	Mexican-Guatemalan hybrid	Kefar Malal-Israel
Shape	Ovoid	Green pear shaped	Elongated pear shaped
Skin when ripe	Pebbly skin turns dark purple when ripe	Skin remains green when ripe	Thin polished green
Texture	Nutty flavour	Outstanding	Little fibre
Oil content	18-23%	16-25%	18-22%
Dry matter	>21%	>23%	ND*
Tree spacing Rwanda	7m x 7m,	7m x 7m	7m x 7m
Tree spacing IR*	7m x 8m	8m x 10m	7m x 8m
Others	Excellent high quality	Cold tolerant cultivar	Transport well

Source: Avocado growing in Kenya by Jurgen Griesbach -2005, ND= Not documented, IR*=International recommendation*

Many of the hybrid grafted cultivars of avocados that include Hass and Fuerte start producing fruits after three to four years of planting however commercial production usually starts after the sixth year

[2] Source: https://www.indiamart.com/proddetail/organic-hass-avocado-20082838673.html
[3] Source: https://www.louiesnursery.com/plants/avocado-trees/fuerte-avocado/
[4] Source: https://www.goodeggs.com/sfbay/goodeggsproducesfbay/organic-large-ettinger-avocado-trio/5fd7bdeabe6089000e90c420

of growth. Non-grafted avocados can take as long as ten (10) years and above before they start producing.

The handbook is designed and presented in easy way to understand pictorial and illustrated sections targeting to assist operators to understand different protocols that ensure maximum understanding of the main concepts of improved avocado post-harvest management and quality assurance.

CHAPTER TWO

Factors Contributing to Deterioration of Avocado Quality after Harvesting

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

Factors contributing to deterioration of avocados quality (Abiotic and Biotic): Causes of deterioration of fruit losses are broadly classified into abiotic (non-living causes) and biotic causes (living).

2.1 Abiotic

2.1.1 Mechanical factors- Handling damages

Fruits are damaged due to application of external pressure through fruit drop harvest methods, compressing fruits in gunny bags and rough handling, mechanical damage occur in the form of cuts bruises or deformation on skin increases processes of respiration, water loss, ethylene production and susceptibility of fruits to microbial infection from the cut or injured section. These damages affect nutritional, shelf life and sensory quality of the fresh produce. In avocados, the damages are caused by use of non-compliant harvest equipment and methods including use of gunny bags, poor stacking of product, uneven transport modes, excess products in harvest equipment among others.

Causes of mechanical damage in avocados: Generally, the damage may be due to impact, compression, abrasion or vibration.

Figure 4: Harvested Avocados in crates but over filled – damage to fruits will result from stacking crates above. *(image © Shivachi)*

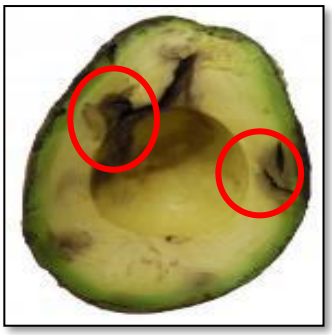


Figure 7: Internal fruit damage due to compression damage *(image © Shivachi)*

Figure 6: Properly packed avocado box - avocado protected from damage *(image © Shivachi)*

Figure 8: Bad practice of avocados transport in open truck causing condensation and compression damage to fruits at base of the pick-up truck *©Aden*

Figure 9: Properly filled avocado in medium crate *(Image © Shivachi)*

Figure 10: Large crates can be used but not filled to the top to avoid compression damage *(Image © Shivachi)*

NB: Mechanical damage may be due to impact (poor harvesting methods such as the dropping of fruit on the ground from height during harvesting or plucking), compression, abrasion or vibration.

2.1.1.1 Compression damage: This happens when produce is subjected to heavy weight, with or without physical movement. 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 Avocados), over-packed, or produce held in containers with poor structural integrity like gunny bags. It generally, results in distortion, cracks of produce and splitting. To limit damages the use of big size crates (jumbo) to hold harvested products while ensuring crate fill is appropriate to avoid damages due to compression as a result of heavy weight of the crate above.

2.1.1.2 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 Avocados wind has been reported to cause scar marks on fruits as a form of wind rub. Use of wind break vegetation along crop blocks is recommended to reduce wind velocity.

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

To avoid that harvest avocado diligently using specialized harvest tools like poles and ladders, never shake trees or drop fruits from heights. Harvested produce should gently be kept into crates or trucks during loading.

2.1.1.4 Vibration damage**:** A type of damage associated with transport and occurs when 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. Controlling this type of damage require leveling of access roads and use of vehicles with good suspension while truck loading need to be done in such a manner that containers are properly secured to ensure no free movement resulting to vibration during motion. During transport securing loads to minimize motion will prevent movement of crates in trucks.

2.2 Environmental factors

Environmental factors such as wind speed and temperature contribute to quality properties of produce through effects on respiration, ethylene metabolism and water loss during fruit growth. High temperature and low humidity increase the rates of physiological processes and therefore leading to dehydration of produce. To mitigate this timely cold storage after harvest and high humidity storage are employed to slow these processes and prolong shelf life.

2.3 Biotic factors

Avocado are affected by living organisms that include microorganisms such as fungi, bacteria, parasites and viruses those are referred to as biotic factors

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

Biological agents in the form of microbes are the main source of spoilage of fruits Majority of postharvest diseases of avocado fruits 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 of pre-harvest origin. Contamination of produce can also occur at pre or postharvest if not properly handled, through improper cultural practices, by actors 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 11: White or grey moulds (Sclerotinia sclerotium) on Avocados[5]

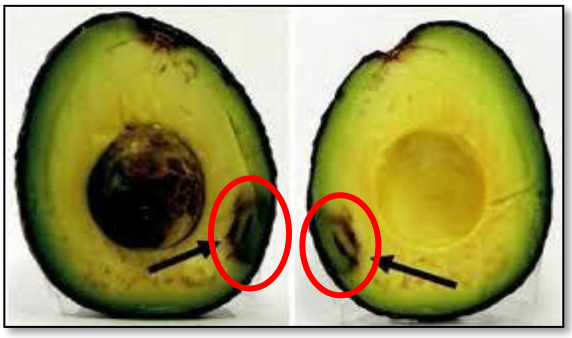


Figure 12: Anthracnose on avocados[6]

It is advisable to maintain hygiene at farm level to reduce spread of microbial cause of damages, which include cleaning of harvesting equipment, Pre-harvest prophylactic spray application especially against fungal infestation.

Prevention measures

- Biotic causes of quality lose require improvement of farm hygiene and sanitation.
- Use of clean harvest and storage equipment.
- Frequent sanitization of harvesting pruners with bleach or alcohol based sanitizer.

2.4 Physiological factors (respiration, transpiration, Biochemical-Ethylene emission)

Factors that lead to deterioration of avocados that are not caused by living organisms are referred to as abiotic factors those are classified as either physiological, respiration or biochemical causes of deterioration.

2.4.1 Physiology

Avocados fruits harvested are composed of living cells and tissues. During harvesting the cut part is separated from the growing medium. Harvested produce has to continue living on stored reserves in form of carbohydrate and water, the 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, leading to undesirable, untimely ripening as a result of senescence hormone, leading to significant quality deterioration before produce arrive in the market.

2.4.2 Respiration

Respiration involves the breakdown of carbohydrates to carbon dioxide, water and heat in the presence of oxygen. The implication of reducing oxygen or increasing carbon dioxide levels (e.g. modified atmosphere packaging, surface coating and controlled atmosphere storage) reduces respiration, preserves quality, and extends shelf life of produce. However, too low oxygen levels and/or too high carbon dioxide levels lead to anaerobic respiration (fermentation) causing physiological disorders and alcoholic flavor (off-flavor) resulting in reduced shelf life of produce. Large sea freight transportation containers use the controlled atmosphere as an effective control of the ripening process leading to considerable.

2.4.3 Effects of uncontrolled respiration of avocados

a) Accelerated respiration occasion losses in form of dry weight, quality deterioration, texture and flavor of avocados.

[5] Source: https://www.quora.com/Is-it-bad-to-eat-an-overripe-avocado
[6] Source: https://www.postharvest.biz/en/news/nca-ratios-in-the-skin-of-unripe-avocado-fruit-at-harvest

b) Avocados just like many fruits are climacteric, they do experience final respiratory acceleration before they senesce or completely deteriorate in quality therefore respiration has to be controlled after harvest.
c) The higher the respiration rate, the faster the rate of quality deterioration and the shorter the shelf life of produce.

2.4.4 Uncontrolled ethylene production

Ethylene (C_2H_4), is a gaseous plant hormone that initiates and accelerates ripening of produce through change of colour also termed as senescence. All plant tissues produce ethylene at varying rates. Fruits produce higher ethylene when compared to vegetables, however climacteric fruits are sensitive to ethylene, thus it is recommended never to mix avocados with high ethylene producers such as banana, passion fruits, avocados and other fruit. When avocados are exposed to prolonged ethylene ripening, avocados defects are noted, control of ethylene emission and effect in acceleration of ripening can be overcome through initial pre-cooling and latter cold storage of produce, a temperature between 5 to 8^0C is recommended for avocados storage.

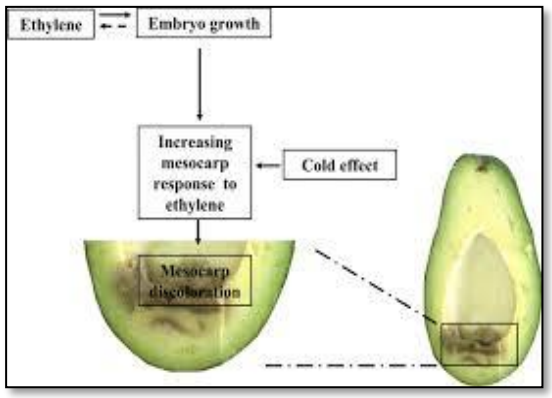


Figure 13: Effects of ethylene on stored avocados[7]

Figure 54: Avocado ripening at storage stage due to exposure to uncontrolled ethylene emissions leading to ripening during storage before packing
© Shivachi

Product segregation between high emitters of ethylene, moderate and low emitters is advisable. For advanced storage, or long-distance transportation such as use of sea transport, ethylene absorbers (potassium permanganate ($KMnO_4$) or scrappers/inhibitors (Methyl cyclopropene or 1-MCP) are recommended.

2.4.5 Transpiration

Transpiration is the action of loss of water through normal cellular activities also referred to as evapotranspiration. Water loss through natural transpiration can increase according to the relative gradient between internal cell water level and that of the air humidity level. The lower the air relative humidity, that is the drier the air is, the higher the rate of water loss through transpiration.

Apart from affecting quality of produce by shortening the shelf life, texture and flavour water loss through dehydration affects saleable weight of produce with a moisture loss > 5% identified as a serious loss leading to shrivelling of produce.

Crops have several natural mechanisms to control loss of water such include waxy surface that reduce rate of transpiration, this is the case of avocados varieties that are waxier tending to hold for a longer time (Shelf life) compared to the less waxy varieties.

To reduce transpiration (water loss), increase the relative humidity by incorporating humidifiers in the cold rooms to increase moisture level of the storage environment to about 85-90% RH and lower the

[7] Source: https://www.researchgate.net/figure/Working-model-describing-the-interactive-effects-of-ethylene-cold-stress-and-embryo_fig8_23983113

temperature of the surrounding this forms a surface barrier limiting loss of water thus controlling dehydration of produce.

Table 2 Perishability index of various horticulture fruits

Rate of perishability		
Product	**Perishability index**	**Potential life (shelf-life)**
Strawberry, blue berry	Very high	<2week
Avocado, celery, pineapple, tomatoes	High	2-4weeks
Lemon, watermelon and mango	Moderate	4-8weeks
Apple pear	Low	8-16 weeks
Dried fruits	Very low	16-36 weeks
Frozen fruits	Extremely low	>52 weeks

2.5 Pest Issues-Entomological considerations

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

A large number of pest attack on avocado occur in pre- harvest activities resulting in economic losses. Based on WTO on phytosanitary about 750,000 insect species are currently known, out of which 450 are considered serious pests. Pests are more destructive at the larva stage leading to large losses. Among them, fruit flies *(tephritidae)* are the most important pests in export trade of avocados. Fruit flies are known to be invasive, during the egg and larvae phase the fruit flies are undetected while they retain ability to withstand lower shipping temperatures usually set between 5-8^{0}C making it an enormous challenge to eradicate. Cold treatment protocols have been designed and found to be effective in eradication of fruit flies in egg and larvae at third instar phase however the required continuous pulp low temperature of 1.5^{0}C or lower for a period of 18 days (*Were et al, 2020*) leads to extensive fruit chill damages therefore not desired. Other pests include spider mites, thrips and false coddling moth (*Thaumatotibia leucotreta*).

2.5.1 Prevention and control measures

Postharvest management of pests should involve the use of insect traps, cold sterilization, biological control through the use of respective pest predators, use of high carbon dioxide exposure and irradiation whenever possible. Chemical control using insecticides should be avoided after harvest and only is done during pre-harvest stages with maximum observation of pre-harvest intervals (PHI) as recommended on the label.

CHAPTER THREE

Common Avocado Post Harvest Defects

Key Highlights: The section equips readers with knowledge on common avocado post-harvest defects and losses and proposes simple control measures applicable to ensure quality fruits that meet market requirements.

3.1 Avocado quality

3.1.1 Fruit softness

Pressure application on fruit is often used to determine the level of softness of fruit, however this method is subjective, an alternative more accurate method is necessary a penetrometer that gives the best results. Penetrometer (Figure 15) is designed to penetrate the fruit depending on the pressure applied.

3.1.2 Procedure of measuring fruit softness using a penetrometer

a) Select an area on the equator of the fruit
b) Remove the outer skin (exocarp) using a blade or knife.
c) Apply the penetrometer tip at the point of the fruit where the skin is removed, gently press the instrument allowing the tip to penetrate the fruit.
d) At the point where the line on the tip is level with the fruit flesh record the pressure readings.
e) For a specific batch of fruit there will be variations in pressure reading of the fruits both in boxes and within respective pallets hence several reading should be taken and a mean calculated.
f) The mean gives an indication of the batch fruit softness, as a guide the below table gives various softness categories depending on market requirements and transport logistics.

Table 6 Fruit softness categorization

CATEGORY	PENETROMETER Mean (PSI)	Market suitability	Suitable mode of transport
Hard	>25	Retail/Wholesale	Sea boats under CA
Firm	15-25	Wholesale/Retail	Sea boats under CA
Breaking	10-15	Retail	Air transport strict temp control
Firm-Ripe	5-10	Frozen/retail ready to eat	Sea boat
Eating ripe	<5	Frozen	Sea boats

CA= Controlled atmosphere- recommended setting of O_2= 3%, CO_2=6%

(Source: California avocado association 2005)

Figure 15: penetrometer used to measure softness of fruits (Image: Shivachi)

3.2. External fruit defects

3.2.1 Sunburn

Sunburn appears on a fruit as a corky, hard or cracked skin usually yellow in colour at the onset to reddish brown or even black in colour depending on solar intensity and exposure duration. Usually appearing on one side of the fruit towards the stem end due to after prolonged exposure to sunlight on the fruit. The damage on the skin extend to the flesh usually leading to abnormal ripening. This defect is most common on exposed fruits especially at the top canopy of the avocado tree with sparse leaf cover.

Figure 16: Yellow patch/sunburn on side facing the sun ©Shivachi

Figure 17: Extensive sunburn appearing as brown patch: © Shivachi

Prevention measures

Ensure canopy cover is adequate at the field level to reduce extensive sunlight exposure to fruits through excessive pruning of branches in the orchards.

3.2.1.2 Lenticel damage

Lenticels are pores of outer plant tissues that function in gases exchange between the atmosphere and the internal plant tissues. Damages to lenticel result in blackening and collapsed lenticels. Damaged lenticels become more pronounced during prolonged storage due to dehydration and enlargement of cells around the lenticel and usually die off due to low temperature exposure.

This defect is more common in the Fuerte and Pinkerton varieties as the fruit remain green even when ripe while for Hass fruit much of the lenticel damage is hidden by the dark purple colour of ripe fruit unless the damage is extensive. Lenticel damage is usually as a result of abrasion damage due to poor post-harvest handling of harvested fruits during picking and transportation to the pack house as well

as during packing of fruits in the pack house. In the packhouse fruit pre-wash section especially if they are dry cleaned with action of brushes during washing or cleaning causing major physical skin damage.

Prevention measures

To limit lenticel damage on fruits, irrigation should not be done on the trees a day before harvesting (to reduce level of fruit turgidity) and avoid picking or transporting fruits during cold and wet weather.

Figure 18: Lenticel damage on Hass Fruit © Shivachi

Figure 196: Lenticel damage dark spots on Fuerte fruit © Shivachi

3.2.1.3 Chilling injury

Chilling injury is manifested through defined areas of black, sunken lesions. Lesions and extensive damages often appear on one side of the fruit and usually the bottom or distal end of the fruit. Depending on low temperature exposure duration internal injury may occur, under short duration usually chill injury do not extend to the fruit flesh. External damages under exposure to disease causing organisms contribute to post-harvest fungal diseases. Less mature fruits, fruits high in nitrogen and low in calcium are more susceptible to chill injury, the injury is caused by use of initial cooling as well as storage and shipping temperature lower than 5^0C. To limit causes of chill injury of fruits an appropriate cooling and shipping protocol is required (avocado temperature management protocol standard operating procedure)

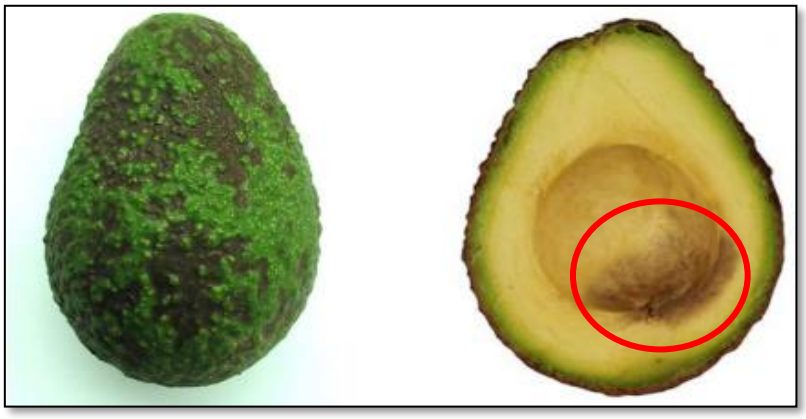


Figure 20: Chill injury. Source: © HAB

3.2.1.4 Thrip damage

Thrips are serious tropical pests affecting fruit development at the early stage resulting in the insect removing the top layer of the fruit skin forming a scar which is usually rough, cocky and brown in colour. The scar remains even after fruit ripening since the damage occurs at the early stage of fruit development. The resultant visual defect reduces export marketability of defective fruits, the best control strategy involves implementation of a good pest monitoring and control program. Affected

fruits can only be used in ready to eat frozen pealed fruit since the damage does not extend to the avocado flesh.

Figure: 21 Scarring caused by thrips Scirtothrips perseae (c) HAB

Prevention and control measures

- Biological control of thrips through introduction of thrips predators in the field.
- Preventive pesticide application to control extensive infestation in the orchard
- Use of integrated pest management approach to reduce occurrence of thrips in the orchards.

3.2.1.5 Limb and leaf rubbing (Scarring)

Affected fruits appear scarred due to abrasion damage on the skin with a brown corky colouration, the affected parts do not change even after ripening. Fruit skin abrasion damage can be caused by leaves or branches rubbing against the fruit usually as a result of wind motion. The use of wind breaks can considerably reduce incidences of scarred fruits, the resultant defects usually affect the external parts of the fruits impacting quality and marketability of affected fruits. Such fruits can be sold ripe pealed and frozen.

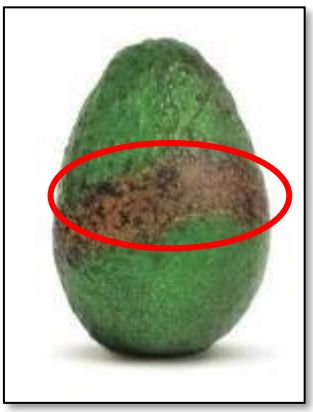


Figure 22: Scarring caused by limb rubbing © HAB

3.2.1.6 Chemical residue

Rarely are chemicals used on avocados in Rwanda however to control orchard fungi infestations, likely to cause post-harvest fruit diseases such as stem end rot and anthracnose different pesticides available locally are used. The pesticide may leave a visible blue-green spray residue on fruits which does not affect the internal fruit quality nor the food safety of the avocado but is unacceptable to customers. Affected fruits should be washed, brushed or wiped off in the pack line to remove the residue. To minimize the effect of residues on fruits it is recommended to use recommended fungicides that are registered by the authorities, respecting the post- harvest intervals and that are easier to clean and remove.

Figure 23: Whitish chemical deposits at the base of fruit © HAB

3.2.1.7 Ridging

Ridging marks are visible fold-like marks on fruit skin surface usually as a result of damage to fruits at very early development stage which may happen during flowering. Ridging can be caused by weather or insect bites visually appearing as an extensive raised portion on the fruit. The raised portion usually appear longitudinally down the fruit of varying width such fruits are usually prone to abrasion damage on the tree due to leaf and branch rubbing on the ridged area. Ridged fruits usually appear misshaped, additional damages may occur during picking, packing or transportation to the packing shed. Ridged fruits are less marketable but could be sold as ripe pealed in frozen state.

Figure 24: Folds on skin surface © Shivachi

Figure 25: Folds on skin surface when same fruit is ripe © Shivachi

Figure 26: Damages on ripe avocado flesh on fruit with ridges image © Shivachi

3.2.1.8 Checkerboard ripening

Checkerboard ripening occurs when fruits in a box have different ripeness phases with some fruits clearly green while others have varying colour shades with difference in purple colour intensity and level of softness of fruits. This is usually a Hass problem and a concern on the ripening process causing challenges in form of multiple handling and increased expensive labour for sorting fruits after receiving the consignment which is mainly occasioned by packing of variable maturity fruit in situations where multiple fruit set periods in a season and older or more mature fruits area mixed with a younger and less mature fruits. It is important for exporters to ensure batches from different fruiting regions are not mixed in a box or pallet to prevent the varying ripening of fruits is a carton or box.

Figure 27: Fruit appearance before dispatch, some fruits are dull green (more mature) and some shiny (immature) in the same box. © Shivachi

Figure 78: Checkerboard ripening observed during ripening process. Image: ©California avocado commission

3.2.1.9 Rodent damage

Rodents usually cause physical damages on fruit skin surface by piecing or gnawing through the flesh rendering the damaged fruit unmarketable. A proper storage pest control protocol is required to keep away rodents in stores, packing areas and fields.

Prevention and/or control measures

Introduce a pest management plan on areas around the harvest shed/farm grading shade.
Avoid farm staff eating close to the farm grading shade or storage areas.

Figure 298: Rodent damage on stored avocado fruits© Shivachi

3.3 Internal fruit defects

Evaluation of internal defects of fruits based on the below parameters is ideal in ensuring exportable quality of avocados to various export destinations. Fruits should be evaluated during pack shed receiving process and sampled for fruits defects then expressed as % of defect for the respective parameter.

3.3.1 Grey pulp

This is an appearance of the fruit interior with an intense diffuse flesh discolouration usually greyish to blackish discolouration in appearance. The greyish discolouration is more pronounced in the distal (bottom) area of the fruit and may extend towards the stem part with occasional accompaniment of vascular discolouration. Grey pulp is prevalent in fruits grown in warmer climates and more significant in fruits that have been harvested late, the main cause is (over mature fruits are more affected), increased length of storage, warmer storage or prolonged low shipping temperature leading to cellular damages due to enzyme Polyphenol oxidase browning reaction. Exposure to ethylene during low temperatures that allow ripening to progress enhances development of grey pulp disorder.

Figure 30: Grey pulp disorder
© HAB

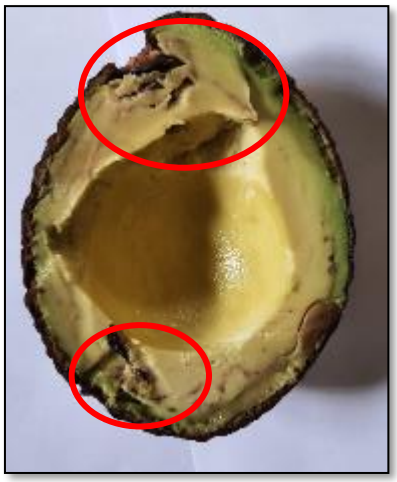


Figure 31: Ripe fruit with grey pulp disorder.
© Shivachi

3.3.2 Stem End Rot

Affected fruits have a brown translucent discolouration in the fruit flesh which starts from the stem end spreading downwards throughout the fruit. Stem end rot is a fungal disease where under severe infestation fruits exhibit a whitish fluffy or pinkish fungal mycelium discolouration may be accompanied by signs of rots. External examination of the fruit shows a blackish decaying zone around the stem end. The main source of infestation is a group of fungi in the field with pruning and removal of dead, decaying branches recommended in addition to normal copper-based fungicides sprays formulations. Warm and wet conditions are favourable conditions for fungal infestation, fruits become infected mainly during harvesting with the fungi entering the fruit through the cut pedicels thus use of clean cut-tool is recommended to prevent cross contamination. Post-harvest sprays may be applied to prevent fruit stem-end rot progression while storage at low temperatures inhibit decay and fungal progression/ spreading.

Figure 32: Pedicel attachment starts to rot[8]

Figure 33: Stem attachment area rots Image
© Madhupani eta al 2017

Prevention and/or control measures

- Sanitation and cleaning of harvest equipment
- Always leave 0.5 inch of stock attached to the fruit during harvesting.
- Avoid harvesting in wet rainy conditions.
- Keep harvested avocados in well ventilated crates and avoid use of gunny bags.

3.3.4 Flesh adherence to seed

The defect result in some portion of flesh being left adhered on the seed when the fruit is cut into half and pulled apart. Partial cause of this is the uneven ripening of fruit with the portion at the top of the seed remaining unripen, hard and rubbery with other portions of the fruit ripening normally. The

[8] Source: http://Plantvillage.psu.edu Avocado | Diseases and Pests, Description, Uses, Propagation (psu.edu)

defect is more common on early maturing fruits while incorrect ripening chamber temperatures may enhance the problem. Marketability of such fruit when sold as ready to eat is reduced.

Prevention and/or control measures

Only harvest mature fruits to prevent partial ripening of fruits. Segregation and processing of batches from single source at a time to avoid mixing of fruits with different levels of maturity.

Figure 34: Flesh adherence to seed Image © Shivachi

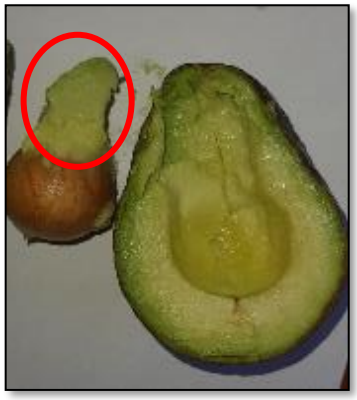


Figure 35: Seed with flesh adherence Image: © Shivachi

3.3.5 Diffuse flesh discolouration

The defect usually appears as grey to blackish discolouration or sometimes brown discolouration of fruit flesh visible in hard fruit stored or shipped. The level of discolouration intensifies as the fruits ripen and increases in intensity once the fruit is cut. This defect affects the internal fruit quality impacting on the normal organoleptic properties of the fruit due to the presence of dead fruit flesh in the fruit. Diffuse flesh discolouration is caused by multiple actions after fruit harvesting key among them is internal chilling injury especially if the fruit is less mature, incorrect controlled atmosphere chamber settings allowing increased carbon dioxide levels with significant reduced oxygen levels (anaerobic conditions), prolonged shipping periods impacting on late session fruit. Another key contributor is fruits with high nitrogen levels and low in calcium which are seen to have higher levels of disorder.

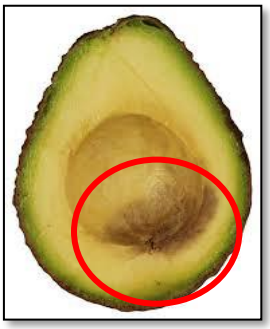


Figure 36: Diffuse flesh discolouration Image © Hass avocado board

Prevention and/or control measures

- Ensure fruit maturity is according to specification.
- Regulate storage temperature of the cold room to a range of 6-8 degrees to avoid chill damage.
- Minimise logistical delays of fruits transported by ship to avoid prolonged cold storage.

3.3.6 Vascular browning

Fruit flesh appear with distinctly black vascular tissues or visible dark brown to when cut. The black or brown discolouration of vascular tissue run longitudinally from the fruit stem to the distal (bottom) of the fruit where it enters the seed. Known causes of vascular browning with symptoms more pronounced at distal of the fruit include internal chilling damage as a result of prolonged low temperature storage for the low maturity level of the fruit.

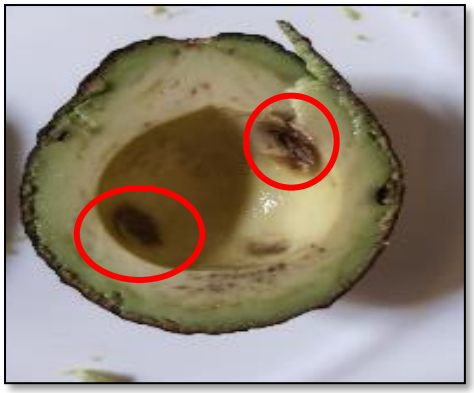


Figure 37: vascular browning image
© S.D Mhlophe

Prevention measures

- Ensure fruit maturity is according to specification.
- Regulate storage temperature of the cold room to a range of 6-8 degrees to avoid chill damage.
- Minimise logistical delays of fruits transported by ship to avoid prolonged cold storage.

3.3.7 Vascular browning and stem end rot

This is a case of advanced decay as a result of multiple disorders with combined stem end rot and vascular browning leading to discolouration of flesh pulp. The key cause of this defect is a group of fungi present in the field with spores spread from dead branches of trees infecting the fruit during warm and wet weather. Fungal multiplication can be controlled through strict cold chain management however initial pre-harvest good agricultural practices such as pruning off dead branches, orchard sanitation and application of copper-based formulation are important control of infestation.

Figure 38: Stem end rot and vascular browning in ripe fruit ©HAB

3.3.8 Black Flesh Bruising

The black flesh bruising is more notable on ripe fruits, fruits appear with grey to black flesh on one side of the fruit usually extending from the seed to the skin affecting middle region (equator) of the fruit. The main cause of defect is the rough handling of fruits during harvesting usually when traditional methods such as tree shaking is used leading to fruits falling with impact on the ground.

Figure 39: Surface damage on fruit due to poor harvesting methods (Fruit drop) © Shivachi

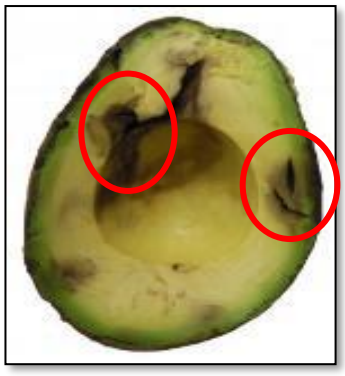


Figure 40: Internal injury due to poor handling. © Shivachi

Prevention measures

- Appropriate harvest methods through use of harvest bags with elongated handle to detach the fruit from the tree and reduce fruit bruising.
- Proper crate fill to prevent surface bruising of fruit from the top crate,
- Avoid use of gunny bags to transport harvested fruits

3.3.9 Stones in the flesh

Ripe avocado fruit may contain hard lumps attached to the skin of ripe avocado that appear like ‘stones” usually about 5mm sticking on the skin. On the outside of the fruit they appear as holes or dark spots and are not harmful when eaten though they reduce the quality of the fruit. Stones are caused by insect damage most commonly by fruit spotting bug, the natural defence action by the fruit lead to partitioning the damaged section caused by insect damage leading to stony line texture when consumed.

Preventive measures

- Early control of fruit pest through sprays, traps or use of integrated pest management technique.

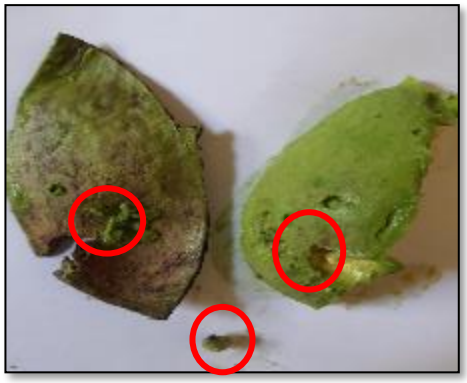


Figure 41: Stone in flesh on skin © Shivachi

Figure 42: Mark of stone flesh detached © Shivachi

CHAPTER FOUR

Avocado Handling and Product Specification

Key highlights of the chapter: The chapter equips the reader with techniques on how to determine mature fruits while on the mother plant through adequate knowledge on maturity indices. The readers are equipped with skills on how to develop a harvest protocol and the harvest requirements during and after harvest.

Typical Mechanised Avocado handling facility

Figure 43: Avocado grading and sorting machine[9]

4.1 Product handling and specification

Avocado producers face challenges in deciding when fruits are ready for harvest. It is common practice in fresh produce production that the ideal harvest stage of different varieties of Avocado determined by market requirements as a measure of ideal condition for consumption commonly referred to as horticulture maturity.

For Avocados harvest maturity refers to time when the "fruit" is ready to harvest taking into account the time required to reach the market and various value chain activities to the market (Avocado can either be exported while ripe or ready to ripen depending on customer requirements and methods of exportation).

Avocado fruit mature on the tree but ripen after picking which is also referred to as climacteric fruit as such it should be harvested at the right maturity stage. The harvest time will need a time lag (harvest earlier) necessary to ensure produce get to the market at ideal maturity.

4.1.1 Types of maturities

- Physiological maturity
- Consumer or horticulture maturity

4.1.2 Physiological maturity

Usually, attainment of full development just prior to ripening or seed development in non-climacteric fruits.

[9] Source: https://reports.weforum.org/enabling-trade-from-valuation-to-action/enabling-trade-from-farm-to-fork/a6-case-studies-f2f/kenyan-avocados-connecting-to-high-value-export-markets/?doing_wp_cron=1613505710.1677761077880859375000

4.1.3 Commercial maturity:

Maturity stage at which growth and development is optimal for specific use. Horticulture maturity is further classified into three different groups that is physiological immature, harvest ripe and firm and mature.

Avocados are harvested firm and mature (stage 1 fig 44) which refers to the situation were the fruits are harvested when they attain certain characteristics such as shape or size other examples include papaya, passion fruits, mangos and bananas.

Figure 44: Hass avocado ripening changes (source: mission produce,Inc),

NB: Fuerte and other green skinned fruits do not change colour when ripe but commonly lose the shiny skin turning yellowish.

4.2 Determination of Avocado maturity (Maturity indices)

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

Avocado visual methods of maturity indices determination:

- Maturity can also be determined by appearance of the fruit. Immature fruit is light green with a shiny appearance while a mature fruit is dark green and an over mature fruit has patches of purple on the skin.
- Maturity can also be determined by seed coat. It's done by cutting unripe fruit into two halves using a sharp knife. If the seed coat is dark brown and tissue thin, the fruit is probably mature.
- Immature fruit may be rejected in the market since it does not ripen well. Determining maturity is most important early in the season.

4.2.1. Use of objective and subjective techniques

a) Odour or aroma through smell
b) Size, shape and colour through sight- shinny or dull skin
c) Texture, hardness and softness through touch
d) Tapping of fruits hear to sound through resonance
e) 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 Avocados harvest stage specification are close in visual appearance.

4.2.2 Disadvantages of subjective techniques in avocado industry.

a. Variation in weather may mislead harvesters
b. Variation in biotic and abiotic factors which may (micro climate) influence the crop judgment (plants near pond/compost pit grows luxuriantly).
c. In a commercial production (large farms) set up area estimation of maturity level of produce becomes tedious thus some mature fruits may be left on the crop leading to losses during next harvest as a result of over maturity.

4.2.3 Physical methods

There are a number of physical methods on maturity test for a variety of fruits. These include: Fruit retention strength, ascetic sound test, skin colour changes, aroma, fruit opening, abscission (depletion of auxins a growth hormone in the fruit), specific gravity and shape of fruits. For avocados, physical methods techniques include use of colour change from shiny skin to dull skinned fruits which is more commonly applied for the Fuerte cultivar.

4.3 Sensory palatability properties

Market requirements for specific grades of avocados is determined by consumer preference. There exists an extensive study on factors that determine consumer preferences which include various sensory properties of the various grade as detailed below. The measure of fleshiness of avocados is used to determine freshness of avocados in the market.

4.3.1 Sensory properties of avocados

4.3.1.1 Texture: Texture is a very important consumer attribute of food. It is a measure in experience on the contact with food and it is indeed as the overall feel the food leaves in the mouth after consumption, comprising of properties that can be evaluated by touch. In avocados, texture is determined by product cellular organelles, biochemical components, water content and cell wall composition. Improved texture in avocados is a product of repetitive genotypic manipulation of avocados fruits through grafting to increase disease resistance while improving the overall texture of the product upon ripening

4.3.1.2 Appearance/colour: All avocados varieties are green in colour when immature however the glossiness and intensity of green colour tend to fade with increase in maturity. Other factors may however change the green colour even though avocados are not mature this includes exposure to ethylene gas, nutrients deficiency, diseases and pests infestation. Fresh avocados exposed to ethylene gas begin to ripen turning purple in colour for Hass while Fuerte varieties begin to soften.

4.3.1.4 Fibrous flesh: Fibrous refers to the amount of fibre present in fruits. Fibre content correlate with cultivars of avocado growers should be able to differentiate the difference between texture-soft, nutty and fibres-stringiness in the practical season. It is also important to note some varieties of avocados have more fibre at same age compared with other varieties. This is an important factor in selection of varieties preferred by the market Hass and Fuerte varieties that have considerably no fibre in the fruits.

4.3.1.5 Aroma and flavour: Hass avocado harvested at correct maturity is known to have little or no grassiness flavour, creamy in nature with hardened taste and nuttier in flavour while immature fruits are grassy and watery in taste.

4.4 Tools for appropriate Quality determination -Instrumentation

a) Microwave oven or Oven
b) Weighing scale
c) Beaker
d) Petri dish
e) Pressure gauge
f) Moisture meter

g) Chopping board
h) Sharp knife
i) Secateurs
j) NIR Dry matter analyser

Common tools for avocado quality analysis

Figure 459: Microwave for dry matter analysis of fruit samples[10]

Figure 4610: Weigh scale for sample weighing[11]

Figure 47: Beaker for sample preparation[12]

Figure 4811: Petri dish for heating samples in microwave[13]

Figure 49: Penetrometer: for measuring fruit softness[14]

Figure 50: Chopping board and knife for sample preparation[15]

Figure 51: Secateurs for cutting fruit pedicel[16]

Figure 5212: NIR Dry matter analyser[17]

Figure 5313: Moisture analyser
© Shivachi

In the absence of tools, simple techniques used to measure freshness of product include visual skin colour check. Mature fruits are dull in colour with sunken distal (bottom) while immature fruits are shiny with protrusion at the base of the fruits. Some of the tools used to determine maturity indices of avocados include moisture meter, pressure gauge and recently the use of non-destructive near infra-red (NIR) technology has been adopted though it remains expensive for many small-scale holders.

[10] Source: https://en.wikipedia.org/wiki/Microwave_oven
[11] Source: https://www.amazon.com/Precision-Analytical-Electronic-Industry-Agriculture/dp/B07X9YHN1W
[12] Source: https://www.indiamart.com/proddetail/glass-beaker-21661504362.html
[13] Source: https://www.amazon.com/Polystyrene-Petri-Dish-60mm-Sterile/dp/B07DX9R8L3
[14] Source: https://www.indiamart.com/proddetail/standard-penetrometer-1195086497.html
[15] Source: https://www.amazon.in/Chefstar-Plastic-Chopping-Board-2-Piece/dp/B07SL5FLZM
[16] Source: https://www.amazon.co.uk/Shear-Joy-Secateurs-Comfortable-Precision/dp/B06XSX4HLR
[17] Source: https://felixinstruments.com/food-science-instruments/portable-nir-analyzers/f-751-avocado-quality-meter/

CHAPTER FIVE
Avocado Harvesting

Key highlights: The chapter equips the reader with techniques on best harvesting practices which once adopted will reduce post- harvest related quality defects that lead in losses, product rejection and affect overall shelf life of harvested fruits.

The readers are equipped with skills on how to develop a harvest protocol and the harvest requirements during and after harvest.

Harvesting refers to the activity of detaching fruit from the mother plant or growing media once presumed ready for consumption, processing or meet consumer specifications. The process and methods of harvesting is a key determinant on various post-harvest aspects of the crop which include quality, texture, shelf life, safety thus require significant attention. Growers should follow the harvesting protocols (SOP on harvesting) and train harvesting teams on the appropriate methods, tools, time participate in supervision of the harvest process.

5.1 Harvesting activity

Harvesting is prompted by maturity of fruits. The main criteria and most reliable method for determining maturity of avocado is by oil /dry matter content (refer to Annex 1 and 2- SOP on oil content determination) and is done in our laboratory by collecting fruit samples from field this is the most reliable method to test maturity.

- Dry matter test must be done before harvesting. The exporter should own the process and share the information with supplier(s) to determine harvest dates. Dry matter test is easy, not expensive and should be common practise.
- Before harvesting, a few representative fruits (of commercial size) should be taken and placed in a clean environment in a room to observe how they ripen at room temperature- whether even or not, and how many days this takes.
- At the farms, farmers can use maturity indices such as the size of the fruit and the appearance of the seed skin to identify when the fruit will be tested.
- Thinning and dark-browning of the seed skin is an indication of increasing maturity of the fruit tissue.

5.2 Harvesting fruits at correct maturity levels have the biggest impact on quality.

- Test the fruit maturity of each orchard to be harvested weekly, in the month preceding usual harvesting date for that orchard.
- Do not harvest before minimum maturity level has been reached.
- Test the fruit maturity level per orchard, weekly, during the harvesting period. Stop harvesting for export once Maximum Maturity level has been reached.
- Harvest selectively (fruits of same maturity levels). Experience, well trained picking teams- better fruit selection.

5.3 Avocado Picking by proper Field Handling

- The harvested fruit should be carefully put into fields crates to prevent damage and moisture build up conditions, mildew, mould and abrasion resistant
- By careful harvesting one can get a higher return for fruits. Remember avocados are easily bruised or scratched and hence rejected.
- Pick fruits when it's not raining to reduce turgidity of fruits which may lead to lenticel damage, also wet conditions are suitable for rots and disease multiplication. Careful handling during picking process will require harvesters to observe the following:
    - Wear cotton gloves.
    - Do not pull fruit from the stalk.
    - Clip the stem as close as possible without injuring the fruit.
    - Lay fruit on the ground with some protection underneath it or use crates if available.
    - Use proper picking equipment such as ladders, pole clippers and canvas picking bags.

- Do not drop fruit as it will cause mechanical injuries.
- Do not overfill field boxes or crates as top fruits will be bruised.
- Store the picked fruit in shade or cover the top box with leaves.
- Transport fruits to packhouse as soon as possible.

Figure 54: Proper in-field collection of harvested avocado- fruits In crates with base crate prevented from direct ground contact @Shivachi

5.4 Fruit sizes

- Fruits are packed according to their sizes
- Sizing is done by machine which determines fruits of the same mass to fall on the same place.
- Fruits size is given by the number of fruits with almost the same mass and added together to make a net weight of 4 Kgs in carton.

5.5 Harvesting tools: Crates /approved bags/Tabs/Knives, picking poles and ladder (containers and tools)

Before use all Tubs & Crates must be cleaned; they should be soaked, cleaned with detergent and rinsed off thoroughly with potable water. They must not be placed directly on soil but rather be placed on a spacer crate or a pallet.

Figure 55: In-field transporting of avocados best done in crates. [18]

Figure 56: Heaping of harvested avocados without crates is bad practice. ©Aden

Figure 57: Heaping of harvested avocados without crates is bad practice. © Aden

[18] Source: https://www.kenyanews.go.ke/mathioya-avocado-farmers-to-enjoy-better-prices-after-striking-a-new-deal/

Figure 58: storing and transporting avocados in bags is not recommended ©Aden.

Figure 59: properly stacked avocado fruits [19]

5.6 Harvesting Methods and time protocol sample

- Harvesters should have short fingernails to reduce the likelihood of causing skin damage during harvest.
- A picking pole with a cutting device (fig 61) at the end can be used where fruit cannot be reached.
- The same end of the pole should have a catching or collecting bag below. The bag should be made from a soft fabric to prevent damage to the fruit.
- The clippers/ cutting device should be clean to prevent spread of a disease.
- **NB:** Sharp clippers should be used during harvesting to severe the stem slightly above the fruits shoulder. The stem length should be 1 cm (0.4 in) or less, to avoid puncture damage of adjacent fruit.
-

Figure 60: Hand snap method (only for fruits near the ground) [20]

Figure 14: Harvesting picking pole attached with bag to prevent fruit drop [21]

Figure 62: Avocado harvest clippers[22]

[19] Source: https://www.latimes.com/world-nation/story/2019-11-20/mexico-cartel-violence-avocados

[20] Source: https://gregalder.com/yardposts/how-to-harvest-avocados/

[21] Source: https://videohive.net/item/harvest-of-hass-avocados-with-pole/23346920

[22] Source: https://www.amazon.co.uk/Shear-Joy-Secateurs-Comfortable-Precision/dp/B06XSX4HLR

Table 4: Correlation of Fruit size with weight of fruits

Fruits size	Weight range in grams
12	300-371
14	258-313
16	227-274
18	203-243
20	184-217
22	165-196
24	151-175
26	<175 - Value pack -10 kg box

Harvesting of avocados is done by hand in Rwanda though mechanization is possible in advanced set up the costs of equipment are out of reach small scale holder who produce the bulk of fruits for export in Rwanda. Harvesters have to be advised on the appropriate methods and tools of harvesting including techniques that reduce wastage through mechanical damages. Crates should not be filled to the brim, to avoid produce damage and give room for air circulation. Pre-grading must be done in the field to remove damaged fruits. Secateurs should be sharp to avoid crop injury and stored overnight in a disinfectant for hygiene to avoid cross contamination.

Figure 63: Damaged crates should not be used image: © Shivachi

Figure 64: *Dirty crates should not be used © Shivachi*

Figure 6515: Clean standard crate for transporting avocados (appropriate fill at the handle slot level) image © Shivachi

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. This prevents potential faecal contamination from rodent and birds prior to use.

5.7 Infrastructure requirements required during harvesting.

Fruits harvested require to be immediately stored in a cool place. At farm level, farmers should build shaded sorting areas from inexpensive materials and temporarily store produce awaiting transfer to grading and sorting pack houses.

Among infrastructure necessary, they include:

- 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 road/path to the block to minimise wastage due to spillage, mechanical damages due to abrasion of produce as a result of vibration.

Figure 66: Charcoal cooling unit @Shivachi

Figure 67 : Poor grading site: likely soil and pathogen contamination of product and poor air circulation on heaped product.(c) Aden

5.8 Cold chain management after harvesting.

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

Pre-cooling systems slow cooling involving the use of simple innovations such as the use of cobalt technique, zero energy units or simple sheds made of insulation materials to avoid exposure of produce to direct sunlight or the use of more sophisticated cooling equipment through forced air cooling, hydro-cooling, vacuum air cooling, contact hydro cooling during washing using very cold water.

Temperature management is a very important aspect in control of quality of avocados after harvesting. Product temperature is approximately 3 degrees more than environmental temperature and keeps rising as long as no controls are undertaken thus leading to deterioration of quality of produce, reduction of shelf life, multiplication of microorganisms and loss of weight.

5.9 Washing of Avocados

- Potable water must be used during washing of avocados to remove soil.
- An appropriate food-based disinfectant at recommended dosage can be added to reduce microbial contamination.
- Wax application can be done if recommended by the customer, the wax must be food grade.

5.10 Avocado losses reduction strategies and technique

5.10.1 Routinely harvest mature fruits to reduce number of overgrown fruits: Avocados varieties are fast ripening fruits once mature. With such a high ripening rate, frequent harvest is required to ensure avocados are harvested within customer specification. This will minimize losses attributed to poor quality due to overmatured fruits. Thorough supervision during harvesting is necessary to ensure no mature fruits are left on the trees.

5.10.2 Ensure Use of hygienic (Cleaned and sanitized) harvesting equipment to prevent spreading of diseases: Harvesting equipment can be vectors of disease spread within a consignment. Producers should ensure equipment such as secateurs or knives used for harvesting are cleaned and sanitized after use. Harvesting equipment must be stored in an enclosed and secure environment overnight to minimize potential contamination through birds and rodent fecal matter.

5.10.3 Avoid over handling and rough handling of the produce: Avocados are delicate in nature and so a reduction in number of handling steps is critical to prolonging of shelf life, reduction of losses and increase in pack out yields. Only absolute necessary steps should be performed. Avocados should be handled with care. Management should provide equipment that are fit for purpose to ease movement of produce both at farm and grading shades. These include crates, trolleys, crates, boxes etc.

5.10.4 Produce holding crates should not be packed too tightly restricting air flow: Compression damage is usually unseen; however, the effect is felt at the market where ripe fruits bear marks of flesh injury leading to low marketability of the affected brand from the country of origin. Tightly packed, overfilled crates do not allow air circulation within Avocados creating conducive environment for anaerobic bacteria to thrive leading to rots on any damaged or injured fruits.

5.10.5 Select for harvest only fruits that conform to correct maturity, leaving immature fruits for the next harvest: Immature fruits tend to have irregular ripening compared to moderate and fully matured fruits. Most immature avocados are graded out and rejected since they do not meet the customer specifications. The fruits have less weight thus decrease the production expectation per orchard. Adequate training is needed to all harvest team on harvest specification.

5.10.6 Harvested produce should be quickly removed from the sun after harvesting: Harvested avocados will start to dehydrate immediately due to physiological processes discussed in module three. To delay processes of respiration and transpiration “Avocados” should be kept in a cool environment immediately after harvest where temperature of 5^0C for Hass and 7^0C for green skinned cultivars such as Fuerte is recommended. Building of harvest sheds is recommended as close as possible to the orchards with access roads clear to facilitate collection and transportation to the zero energy cooling units/packing shade.

5.10.7 Grading should be done to remove diseased, damaged and defective avocados: One of the leading factors contributing to post-harvest losses is presence of diseases in harvested avocados. Most bacterial, fungal and parasitic organism have ability to withstand low temperature especially when in spore form. To reduce progressive development of diseases within the value chain diseased, damaged and defective fruits need to be removed from harvested produce as soon as possible.

CHAPTER SIX

Avocado Storage

Key highlights of the chapter: The readers are equipped with technical skills on various storage requirements necessary to maintain avocado qualities en-route to the market**.** The cost and advantages of improved storage facilities in maintaining quality of avocados.

6.1 Produce storage

Appropriate storage of harvested avocados is critical in the realization of desired market quality. 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.

Why store avocados under cold conditions:

- For preservation
- For maintaining nutritional quality and customer quality specifications
- To reduce losses due to wastage.
- Ensure availability of produce for consumption and processing based on market based on market demand.
- Increase shelf life due to long shipment periods (> 21 days)

Avocados stored under optimum temperature of 5-7^{0}C and relative humidity conditions of (85%-90% RH) will maintain customer quality specification for a period > than 30days. Maximum care is required to ensure concentrations of the gases such as oxygen, carbon dioxide, and ethylene in the storage atmosphere are within acceptable range of 2-3% and 5-6% during storage. For shelf life of the product to be maintained it is advisable to avoid mixing avocados with other crops that emit huge amounts of ethylene such as bananas, passion fruits, chillies, and tomatoes during storage prior to sea transportation.

Some combinations of products during storage can stimulate change of colour of harvested avocados leading to ripening.

6.1.1 Factors that influence storage duration of avocados 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.

Relative humidity (RH 85%) and temperature are the most important components in farm avocado storage set up with variation in setting depending on product important in enhancing the shelf life of produce.

There are various low-cost technology used for storage of produce for other produce listed below:

1. Zero energy charcoal cooling units: This involve 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 5: Avocados ideal storage requirements at various value chain stages

Avocados point of storage	Facility requirements					
	Humidity RH%	T^{0}C	Ethylene	Reason for storage	Maintenance requirements	Action by
Harvesting sheds	70	12-15^{0}C	Nil	Await transport to grading shed	Minimal	Farmer
Zero energy units	75	9-12^{0}C	Nil	Awaiting exporter to pick	Minimal	Farmer
Grading shed	75	10^{0}C	Nil	Awaiting transport	Moderate	Farmer
Pack house cold rooms	85	5-7^{0}C	Nil	Market demand, freight availability	High	Exporter

6.2 Good practices during farm storage of harvested products

At harvest temperature of fruits and vegetables is normally very close to ambient air temperature in the tropics this would range between 25-30^{0}C but may vary depending on weather conditions. In some instances, the temperature may be as high as 38^{0}C. At such high temperature the respiration rate of the product is usually extremely high. *The higher the rate of respiration (higher storage temp) 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. Pre-cooling (Figure 6.1) assist in prolonging shelf life of highly perishable produce such as avocados, leafy vegetables and sensitive fruits such as strawberry.

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

In recent time research has shown 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 68: Modern pre-cool cold storage.[23]

Figure 69: innovative zero energy cold storage for fruits in farms[24]

6.3 Temperature management during storage

Storage structures in form of collecting centers, grading sheds with one modern pack house and airport cooling facility. Cooperatives 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 fans to

[23] Source: https://www.karalsogutma.com/en/our-products/cold-rooms/cold-room/
[24] Source: http://energypedia.info-Evaporative cooling chamber - energypedia.info

allow faster cooling. Always keep produce off the floor, use of plastic pallets or empty spacer dedicated crates is recommended.

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

Field heat removal is critical in ensuring harvested avocados meet desired shelf life and quality requirements through slowing physiological processes that contribute to senesces such as respiration and transpiration during transport, storage and on arrival to customers. Effective removal of field heat is mainly achieved through use of pre-coolers (forced air mechanism) in the shortest time possible (Fig 5.1). Slow cooling is an alternative however efficiency and results are likely not to be appropriate especially where large volumes of produce is involved.

6.4 Segregation and traceability requirements during storage.

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

6.5 Product weighing

Fruits coming from the fields must be weighed and inspected for respective grade and individual weight recorded to gauge picker performance and understanding of quality requirements.

CHAPTER SEVEN

Avocado Transport

Key highlights: This chapter equips readers with knowledge on effects and impacts of the various transport modes in the avocados value chain.

7.1 Avocados transportation

Transport of fruit from the harvest field to temporal storage facilities or from different sources (farms) to the final packing shed is important in eventual fruit quality.

Transport planning can be complex depending on level of growers' complexity in the country it may entail short distance movement of harvested fruits with multiple stops to allow loading of fruits from small holders or cooperatives to long distance travel within the region to shipping ports.

There are multiple factors to be considered during planning for fruit transport to ensure optimal fruit handling under different situations with the key parameter being maintaining cold chain to prevent premature ripening and loss of shelf life.

Correct choice of temperature settings and maintaining a tight cold chain is a key concern, before loading begins key loading protocols should be adhered to which include pre-cooling the truck to currying temperature, ensuring cleanliness, ensuring functioning of cooling units through calibration and use of data loggers to monitor temperature fluctuations.

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

Transportation of avocados from farm to pack house through to the airport or sea ports, should be done in recommended trucks with refrigeration capacity that are capable of maintaining temperature of the consignment.

Figure 7016: Truck loading in a dock shelter Image © Shivachi

Within the farm to the pack house transport of avocados or other commodities can be facilitated by use of covered trolleys or tractor trailers. In case a farm is well mechanised pickups can also be used Trucks used for product transportation should not be used for waste transportation due to risks of microbial cross contamination.

7.3 Temperature management during transport (inter farm and airport transfer)

At farm level it may not be possible to measure temperature of produce during transport however in case there are no refrigerated trucks and a non-refrigerated closed truck is used for transportation, always open the truck for a few minutes before loading fresh produce to allow cool air circulation. Non-refrigerated trucks should have ventilation large enough to allow circulation but positioned strategically to limit entry of dust into produce while transporting produce to the pack house.

Since avocados are primarily grown by small scale growers which necessitate aggregation before supply to pack houses, large trucks should be discouraged to avoid long holding of harvested fruits awaiting achievement of critical mass necessary for transportation to processing sites. The long

holding of fruits in enclosed non-refrigerated trucks could lead to ripening of fruits before arrival in pack house leading to fruit quality degradation and rejections upon arrival.

Figure 71: Farm non-refrigerated transport truck

Figure 7217: short distance pack house to airport refrigerated truck © Shivachi

Figure 7318: Poor handling of avocados during transportation[25]

7.4 Long distance transport

Transportation in refrigerated trucks should have temperature set at 5-8 degrees of the refrigeration unit. Finished product by sea transport are best transported in controlled atmosphere (CA) containers with carbon dioxide and oxygen settings (CO_2=6% and O_2= 3%) critical to maintaining fruit quality while ethylene is removed via use of ethylene scrubbers in the container. All wood used to secure avocados in form of pallets must be treated in accordance to EU regulation 94/62/EC on packaging materials.

[25] Source: https://www.bizcommunity.co.ke/Article/111/641/173221.html

Figure 74: Neatly stacked, packed avocado © Shivachi

Figure 75: treated pallets (legal equipment) ©Shivachi

Figure 7619: Fork lift loading © Shivachi

Figure 77: 40ft container loaded for sea transhipment © Shivachi

7.5 Product hygiene and sanitation requirements

Hygiene and sanitation are critical to safe realization of safe produce, the following should be observed during farm transport of produce to pack houses.

(a) Truck driver assistants (turn boys) handling the produce must observe the picking hygiene requirement.
(b) Maintenance of truck should be done ensuring no oil leaks.
(c) Daily cleaning of truck with records maintained.
(d) Produce handlers must be issued with protective clothing which include: Overcoats, head gear and gloves.

7.6 Stacking and segregation during loading and offloading.

During long distant transport avocados pallets should be stacked such that air movement through the fruit is ensured by tightly packing the pallets or air restricting in cases where trucks are not full to ensure cold air passes through the fruits. During long distance, transport of avocado should not be mixed with climacteric fruits (banana, peaches, kiwi fruits, mangos, or tomatoes) since they emit ethylene which may initiate ripening therefore affecting the shelf life of the fruits. During short distance transport co-loading with other products can be done but the truck body must be free from dust and produce covered with a moist hessian cloth to keep produce on transit cool and hydrated.

 banana	 Peaches	 Apples
 Kiwi fruits	 Mangos	 Tomatoes

Figure 78: Signage for loading area - non compatible products[26]

7.7 Transport equipment

Loading and Offloading equipment should be maintained readily available at all time, the equipment must be adequate for loading and offloading within the shortest time possible. The loading and offloading ramps should be made to enable truck offloading and loading be carried out efficiently. Smoke emitting folk lifts are not ideal in enclosed sections since they emit carbon and heat contributing to the increase in temperature in the cold rooms.

Figure 79: Truck offloading trolley © Shivachi

Figure 80: bulk loading of palletized skids © Shivachi

7.8 Documentation and records.

Records for delivery 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 should be maintained.

[26] Source: https://www.google.com/search?q=no+banana+signs&sxsrf=ALeKk02Cy18UhqZShBi7t1DKFFHCQAtI3w:1614194894974&tbm=isch&source=iu&ictx=1&fir=xveGFjA4QZ0wRM%252C-u9HKx9A6XBK9M%252C_&vet=1&usg=AI4_-kT0T0bHMVlaJ3W4iIB4u9O6kk_UvA&sa=X&ved=2ahUKEwjGqsDKoIPvAhV4QUEAHRtRB8gQ9QF6BAgCEAE#imgrc=xveGFjA4QZ0wRM

References

Cañete, M. L., De Los Cobos, R. P., & Hueso, J. J. (2018). Influence of harvest date on sensory quality attributes of avocado 'Hass.' *Acta Horticulturae*, *1194*(March), 1127–1131. https://doi.org/10.17660/ActaHortic.2018.1194.161

Crowley, D. E., Smith, W., Faber, B., & Manthey, J. A. (1996). Zinc fertilization of avocado trees. *HortScience*, *31*(2), 224–229. https://doi.org/10.21273/hortsci.31.2.224

Date, R., Protocol, A. H., & Date, I. (2020). *Harvesting Protocol*.

Fm, N., Preti, S., Mc, R., Siligato, R., & Stancanelli, G. (2019). *Bactrocera dorsalis Pest Report to support ranking of EU candidate priority pests*. *May*, 0–45. https://doi.org/10.5281/zenodo.2786921

Gilligan, T. M., Epstein, M. E., & Hoffman, K. M. (2011). Discovery of False Codling Moth, Thaumatotibia leucotreta (Meyrick), in California (Lepidoptera: Tortricidae) . *Proceedings of the Entomological Society of Washington*, *113*(4), 426–435. https://doi.org/10.4289/0013-8797.113.4.426

Hofshi, R., Arpaia, M. L., & Fruit, W. (2002). *Avocado Fruit Abnormalities and Defects Revisited*. *1996*.

Information, R., & Read, P. (2001). *Avocado information kit Reprint – information current in 2001*.

Mill, P., Antillean, W. I., & Arpaia, M. L. (2015). *Avocado Postharvest Handling Arpaia , Mary Lu " Avocado : Postharvest Handling Systems " Postharvest Technology of Horticultural Crops Short Course 2015 (c) Postharvest Technology Center , UC Regents Postharvest Diseases What we know about the avocado f*. *2015*(c), 1–7.

OECD. (2004). International Standardisation of Fruit and Vegetables (Avacado). *Oecd*, 130.

Omolo, P., P, T., C, M., E., O., H, O., & K., O. (2011). Analysis of avocado marketing in Trans-Nzoia district, Kenya. *Journal of Development and Agricultural Economics*, *3*(7), 312–317. http://www.academicjournals.org/JDAE

Peterson, E. B., & Orden, D. (2008). Avocado pests and avocado trade. *American Journal of Agricultural Economics*, *90*(2), 321–335. https://doi.org/10.1111/j.1467-8276.2007.01121.x

Raw, A., Specification, M., Name, L., Condition, S., & Sunlight, A. (2020). *Colour / Maturity Green and firm avocado , without defects Appearance*.

Yearsley, C., & Lallu, N. (2001). Symptoms of Controlled Atmosphere Damage in Avocados. *New Zealand Avocado Growers' Association Annual Research Report*, *1*, 26–32.

Annex 1:

Oil content and dry matter determination standard procedure

MICROWAVE OVEN METHOD (Oil-Plus-Water Constant Method)

EQUIPMENT AND ITEMS

a) Microwave Oven (***also commonly referred to as a microwave – an oven that uses micro-radiation waves as source of heat***)
b) Sharp knife
c) Scale (sensitive to 0.01g.)
d) Pen and a sheet of paper
e) Plate/Petri Dish/Glass-Slide
f) Calculator.
g) Grater & Chopping board
h) Avocado fruit(s)
i) Correlation tables

METHODOLOGY

a) Randomly pick sample (e.g. 5 fruits) from a batch no.
b) Cut the top of the fruit and half it lengthwise using the sharp knife.
c) Peel off completely the green portion of the flesh.
d) Using grater get small thin slices of inner flesh of the fruit from both halves.
e) Mix the small avocado slices.
f) Place the **P**late/Petri Dish on the scale and record the weight (**P**)
g) Transfer **10g** (or more) = **F**resh Tissue Weight of the avocado slices by placing them on the plate/petri dish/glass-slides and record weight (i.e. **F** = Petri Dish + Fresh Tissue)
h) Spread the avocado slices on the plate without compacting them.
i) Microwave the avocado slices in plate/petri dish until completely dried to Constant Weight. (Put the plate/petri dish/glass-slides and the weighed avocado slices into the microwave. It must be checked beforehand, for this thickness of the sample slice, that the desiccation is constant and that no brown colouration due to burning will appear. Establish a power of 800 W and after 10 minutes, weigh the sample directly, without allowing it cool in the desiccator. Return the sample into the microwave for 1 minute and weigh it again. Repeat the process until the weight is constant or the difference of the mass between two consecutive weightings is not greater than 0.5 mg. The total of desiccation ranges between 10 and 15 minutes - depending on the volume of the avocado slices on the plate/petri dish/glass-slides).
j) Weigh the Petri dish containing **D**ried Tissue and record the **D**ry weight (**D**)
k) Calculate the **% Dry Matter** i.e. Dried Wt / Fresh tissue wt x 100
l) Calculate the **% Water** (Moisture Loss), then subtract % Water from the **Constant** to get the **%Oil Content**

CALCULATION

% Dry Matter = [(D-P) / (F-P)] x 100	**i.e. Dried Wt / Fresh tissue wt x 100**
% Water = [(F-D) / (F-P)] x 10	i.e. 100% - % Dry Matter
% Oil = Constant – [100 % - [(F-D) / (F-P)] x 100	i.e. Constant - % Water

Where,

P = **P**etri dish weight (*Original Wt. of Petri dish*)

F = **F**resh tissue gross weight (*P + 10g. of avocado fresh thin slices*)
D = **D**ried tissue gross weight (*P + Dried Weight after microwaving*)

a) Original wt of Plate/glass-slide = (**P**)
b) Fresh wt (**F**)= Q +10g of avocado fresh small thin slices
c) Dry wt (**D**) = (Wt after microwaving)
d) Moisture loss (**x**) = F-D

Therefore; % Moisture content = 100 x (X/10g) and

% Oil content = KH - 100 (X/ 10g)

NOTE: Recommended % moisture content at receiving for export varieties is 77- 80**.**

(S.K. Lee and C.W. Coggins, Jr)

According to **S.K Lee** Percentage oil content of a particular variety is given by the difference between its constant and percentage moisture content. This constant varies from one variety to another. For example, for Hass and Fuerte is as given below.

Variety	**Constant (K)**
Hass (H)	(KH) = 87.9 %
Fuerte (F)	(KF) = 89.8 %

Example in Hass variety:

P = **P**etri dish weight (*Original Wt of Petri dish*) = 5.00g.
F = **F**resh tissue gross weight (*P + 10g. of avocado fresh thin slices*) = 15.00g
D = **D**ried tissue gross weight (*P + Dried Weight after microwaving*) = 7.20g

a) % Dry Matter = **[(D-P) / (F-P)] x 100** i.e. Dried Wt / Fresh tissue wt x 100
= [(7.20-5.0) / 15.0 – 5.0)] x 100
= [2.2/10] x 100
= 22 %

b) % Water = **[(F-D) / (F-P)] x 100** or simply 100% - 22%
= [(15.0-7.2) / (15.0-5.0) x 100
= 7.8/10 x 100
= 78 %

c) % Oil = Constant – **[(F-D) / (F-P)] x 100** i.e. Constant - % Water
= KH % – 78 %
= 87.9 % – 78 %
= 9.9 %

NB: To be more accurate you can have >10g sample of fresh avocado flesh thin slices.

Annex 2:

OVEN METHOD (Oil-Plus-Water Constant Method)

EQUIPMENT AND ITEMS

a) Oven – with capacity to operate at 105^0C. (***a thermally insulated chamber used for the heating, or drying of a substance / desiccation***)
b) Sharp knife
c) Scale (sensitive to 0.01g.)
d) Pen and a sheet of paper
e) Plate/Petri Dish/Glass-Slide
f) Calculator
g) Grater & Chopping board
h) Avocado fruit(s)
i) Correlation tables

METHODOLOGY

(Same Principle as Microwave Oven above)

a) Weigh each **P**etri dish/Plate/Glass slide and take note of the weight (**P**).

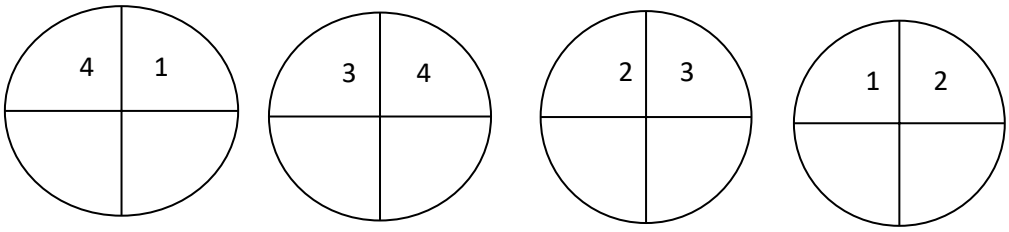
NB. Each Petri dish can represent a batch No.

P Weight of **P**etri Dish	**F** Weight of **F**lesh (+ Petri Dish) prior to Drying	**D** Weight of **D**ry Matter (+ Petri Dish) after Drying
e.g. 5.00g		

b) Cut the fruit longitudinally in two parts, eliminating the seed and the seminal tegument.

c) From one of the parts of the fruit, four 1.5 mm-thick slices must be cut with the help of the slicer.

d) Slices must be divided into four portions, cutting the diameters from largest to smallest. Then, deposit the four portions of the 4 slices without overlap, on four numbered glass-slides, according to the following schema of the slices divided in four and the number of the glass-slide where you are setting each quarter:



e) Weigh each Petri dish which contains the **F**resh Tissue sample and record the weight (**F**) i.e. Weight of **F**lesh (+ Petri Dish) prior to Drying

P Weight of **P**etri Dish	**F** Weight of **F**lesh (+ Petri Dish) prior to Drying	**D** Weight of **D**ry Matter (+ Petri Dish) after Drying
e.g. 5.00g	e.g. 15.00g	

f) The oven should be warmed to the required temperature (105˚c) before placing the samples inside the oven.

(An accurate thermometer placed in a cup filled with oil can be placed inside the oven to achieve the most accurate temperature readings)

g) Place the samples in the oven. Dry the samples in the oven for 4 hours at 105˚C (or 1 hour at 150^0C)

h) Weigh each Petri dish which contains the **D**ry Matter sample and record the weight (**F**) i.e. Weight of **D**ry Matter (+ Petri Dish) after Drying.

P Weight of **P**etri Dish	**F** Weight of **F**lesh (+ Petri Dish) prior to Drying	**D** Weight of **D**ry Matter (+ Petri Dish) after Drying
e.g. 5.00g.	e.g. 15.00g	e.g. 7.20g

i) Calculate the **% Water** (Moisture Loss), then subtract % Water from the **Constant** to get the **%Oil Content**

Example in Hass variety (*as above readings*):

P = **P**etri dish weight (*Original Wt of Petri dish*) = 5.00g.
F = **F**resh tissue gross weight (*P + 10g. of avocado fresh thin slices*) = 15.00g
D = **D**ried tissue gross weight (*P + Dried Weight after desiccation*) = 7.20g

a) % Dry Matter = **[(D-P) / (F-P)] x 100** i.e. Dried Wt / Fresh tissue wt x 100
= [(7.20-5.0) / 15.0 – 5.0)] x 100
= [2.2/10] x 100
= 22 %

b) % Water = **[(F-D) / (F-P)] x 100** or simply 100% - 22%
= [(15.0-7.2) / (15.0-5.0) x 100
= 7.8/10 x 100
= 78 %

c) % Oil = Constant – **[(F-D) / (F-P)] x 100** i.e. Constant - % Water
= KH % – 78 %
= 87.9 % – 78 %
= 9.9 %

CORRELATION TABLE

Variety	**Constant (K)**	**Minimum % - at Receiving**		
		% Water [100 % - % DM]	**% Dry Matter** [100 % - % Water]	**% Oil Content** [Constant (K) - % Water)]
Hass (H)	(KH) = 87.9 %	79	21	8
Fuerte (F)	(KF) = 89.8 %	80	20	9
Pinkerton		80	20	
Ettinger		80	20	
Reed		80	20	
Nable		81	19	