A food system analysis of Kenya's mango, avocado and poultry sectors

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Kenya is considered one of the economic powerhouses of eastern Africa. The agri-food system contributes 34 percent of the total national GDP and 65 percent of all export related earnings. More than 80 percent of the Kenyan population is directly dependent on agriculture as a source of food and income.

Due to inefficiencies in the supply chains, vast volumes of perishable, nutrition dense food products are lost before they reach the market or consumers.

Post-harvest losses of over 40 percent are common in the case of perishable and nutrition dense agricultural products such as fruits and vegetables and fresh animal products.
Reducing post-harvest losses enhances the efficiency of the food system, reduces waste, minimizes environmental footprint of agricultural production, and makes more food available, accessible and affordable for consumers.

Keywords: Food Systems, food loss and waste, agro-processing, agro-logistics, Kenya

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Photo cover: Emily Osena

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List of Acronyms

AFA	Agriculture and Food Authority
C	Celsius
EU	European Union
EUR	Euro (Currency)
FLW	Food losses and waste
FOA	Food and Agricultural Organization
FPEAK	Fresh Produce Export Association of Kenya
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
HCD	Horticultural Crops Directorate
KALRO	Kenyan Agriculture and Livestock Research Organization
KEPHIS	Kenyan Plant Health Institute
KFC	Kentucky Fried Chicken
KNBS	Kenyan National Bureau for Statistics
KSH	Kenyan Shilling
MTP	Mid Term Plan
NGO	Non-Governmental Organization
PCB	Pest Control Board
PPP	Private Public Partnership
SDG	Sustainable Development Goals
USD	US Dollar

Preface

It's my pleasure to present to you the study *"A food systems analysis of Kenya's mango, avocado and poultry sectors, assessing opportunities to reduce food losses".* This study is commissioned by the Ministry of Agriculture, Nature and Food Quality (LNV) in direct coordination with the agricultural department of the Netherlands Embassy in Nairobi, Kenya. The study is carried out by Wageningen Centre for Development Innovation.

Kenya and the Netherlands have a long history of collaboration stimulating sustainable trade and investment in the agricultural sector. Within the agricultural domain, mitigating food losses and waste, creating added value for agricultural products and generating employment opportunities are among the shared ambitions of Kenya and the Netherlands. Kenya's growing population and progressive exposure to climate variability is increasingly putting pressure on food supplies and natural resources. In order for Kenya's food system to be able to sustainably feed and create employment opportunities for this growing number of people, strategic considerations must be made to transition to more sustainable, inclusive and resilient modalities of producing and consuming food.

The ultimate goal of this study is to identify critical leverage points to reduce food losses through agro processing and agro logistics. The study will serve to inform the programming of the Ministry of Agriculture and the Netherlands embassy in Kenya and form a basis for dialogue with Kenyan partners and Dutch businesses. The study highlights how effective reduction in food losses has the potential to contribute towards a number of Sustainable Development Goals, amongst others SDG 1: No poverty, SDG 2: Zero hunger, SDG 5: Gender equality, SDG 8: Decent work and economic growth, SDG 9: Industry, innovation and infrastructure SDG 12: Responsible consumption and consumption, SDG 13: Climate action and SDG 17: Partnerships.

In order to produce, process, distribute and consume food sustainably and efficiently, all stakeholders in the food system, ranging from food producers to consumers need to take action. We cordially invite you to read this study that provides valuable insights for the establishment of partnerships and collaborations to address food losses and contribute to the strengthening of Kenya's agricultural sector.

I would like to thank Mr. Herman Snel, the food system analysis team leader from Wageningen Centre for Development Innovation and Ms. Inge Tenniglo, regional coordinator Africa of the Ministry of LNV, in the Netherlands for their contribution and support. Also a special thanks to all the stakeholders in Kenya who contributed to this report for their insights and efforts.

Ingrid Korving
Agricultural Counsellor for Kenya and Tanzania
Embassy of the Kingdom of the Netherlands

Executive summary

Kenya is considered one of the economic powerhouses of eastern Africa. The agri-food system is one of the fundamental pillars of the national economy witnessing steady growth over the last 10 years. The agri-food system contributes 34 percent of the total national GDP and 65 percent of all export related earnings. The agri-food sector is largely informal.

More than 80 percent of the Kenyan population is directly dependent on agriculture as a source of food and income. Kenya's agricultural sector has improved significantly in recent decades in terms of production, productivity and growing orientation towards the export market. Nevertheless, the successes achieved have not yet led to structural improvement with regard to food security and poverty alleviation in Kenya itself.

Over the last two decades, significant progress has been made in meeting the caloric requirements of Kenya's rapidly growing population. Nevertheless, statistics point to an increase in malnutrition and a sharp increase in overnutrition over the past 30 years, driven by changing dietary habits in which the consumption of fresh fruits and vegetables and the intake of high quality proteins is less prominent.

Agricultural production and productivity have grown significantly in the last 20 years, non-the-less due to inefficiencies in the supply chains, vast volumes of perishable, nutrition dense food products are lost before they reach the market or consumers. Food losses affect both small-scale and commercial producers, as well as middlemen, suppliers, distributors, traders, exporters, wholesalers, consumers and national governments.

Food losses do not only affect the economic income of stakeholders but they also affect the local availability and affordability of nutritious and essential food products for consumers. In addition, these food losses are related to inefficiencies that have a negative impact from an environmental and a socio-economic point of view. In the context of Kenya, post-harvest losses of over 40 percent are common in the case of perishable and nutrition dense agricultural products such as fruits and vegetables and fresh animal products.

Reducing post-harvest losses enhances the efficiency of the food system, reduces waste, minimizes environmental footprint of agricultural production, and makes more food available, accessible and affordable for consumers. In Kenya there are numerous economic opportunities to invest in mitigation and reduction of post-harvest losses, that can contribute to more efficient, sustainable, resilient and circular food systems.

In Kenya's mango, avocado and poultry sectors there is a substantial difference in post-harvest losses when comparing large scale, commercial (export oriented) supply chains with small-scale, informal supply chains destined for the domestic market. Losses in the large scale (export) sector range between 5 percent in the industrial poultry slaughtering industry and 15 percent in the avocado export sector. In contrast, losses in the domestic value chains of mango and avocado reach beyond 35 percent (and this is considered a very conservative estimate). Considering that the volumes of mango, avocado and poultry, destined for the domestic market are much bigger than the volumes destined for the export market (roughly 3:1 for all three value chains), The potential gains in reducing post-harvest losses are considerably higher when focussing on the domestic market rather than the export market.

There are numerous opportunities to effectively reduce losses in Kenya's mango, avocado and poultry sectors. Addressing the root causes of losses requires taking on a food systems approach whereby enabling policy conditions are combined and bundled with a series of complementary interventions addressing good agricultural production practices upstreams with suitable technological interventions and also including interventions throughout the supply chain level such as vertical and horizontal

supply chain integration, improved post-harvest handling and transportation services, value addition and market information systems. Effective reduction of losses requires a systemic approach with enabling policies that support improved sector collaboration and create incentives to invest in loss reduction.

The technical solutions that are available for reducing post-harvest losses are many, and they often inter-related. In this report a distinction is made between "*desired integrated interventions*" and "*business opportunities*". The "desired integrated interventions" refer to a host of elements geared towards development of the production stage and collaboration throughout the sector. These integrated interventions are diverse and include, amongst others: training of farmers, traders, and vendors as key actors (Good Agricultural Practices, product handling, Integrated Pest Management, etc.), integrated sector coordination (improving access to market information, traceability, formalized contractual arrangements, market linkages), enhanced enabling policy environment (with incentives and regulations addressing post-harvest losses), improving access to agri-finance products, improved rural infrastructure (roads and storage) and, organizational strengthening of producer organizations.

In addition to the aforementioned "desired integrated interventions", this study identifies six *business opportunities* which have potential to reduce food loss, generate a positive economic impact for the sector, and meet the requirements of potential (Dutch) investors or product suppliers. For the avocado/mango chains these include investments in temperature-controlled storage, aggregation facilities, packaging solutions and processing technologies. For the poultry value chains these include industrial slaughtering facilities and rendering facilities.

The six business opportunities have strong potential to contribute to the reduction of post-harvest losses. In the mango/avocado chain it is estimated that post-harvest losses can be reduced by 30-60 percent by investing in temperature controlled storage. When aggregation facilities and related agri-logistics systems are in place and efficiently managed a maximum of 20 percent loss can be reduced. With effective packing solutions and shelf-life extension techniques along the chain yet another 30-40 percent losses can be reduced. Post-harvest value addition and processing can reduce a maximum of 10 percent of the losses by using low-quality fruits that otherwise would be lost.

For the case of the poultry supply chain, the potential reduction of losses in the industrial slaughtering and processing sector is limited as the industrial poultry sector in Kenya is well-organised. Reduction of losses can be gained especially in the small-scale poultry sector supplying live chickens to wet markets (meeting 70-80 percent of the poultry consumption in Kenya). In that domain much can be gained through regulations and practices that improve transportation practices of live chickens and, regulate hygiene, biosecurity and food safety standards. 30 percent of the chicken carcass (feather, intestines, etc.) is not consumed and considered waste. Rendering technology can turn that waste into useful products such as animal feed. As such a 30 percent post-harvest loss is turned into use contributing to a circular economy.

Dutch solutions in storage, aggregation, packaging and processing can be very valuable in the Kenya avocado and mango sectors but especially related to export as that sector better fits the scale and investment power of Dutch companies and service providers. In that case the purpose in not so much to reduce post-harvest losses (which are low already) but to tap the growth potential of both sectors that is promising to be substantial.

For the domestic market sector the most promising technology that can substantially reduce post-harvest losses in mango and avocado is in the cold storage chain, preferably in an integrated form including very small, low-cost, appropriate technology solutions such as on-farm charcoal evaporative coolers; medium-scale cold storage container solutions at local aggregations localities; and large scale cold stores at urban markets (with refrigerated transport in between). Especially the medium scale cold storage container is regarded as feasible and effective investment to bring down food losses. This technology is readily available in Kenya either as product from the shelf, or as part of a service agreement in which the user pays per kg of storage, and management is done by the owner company.

A cost-benefit assessment of such technology showed profitability for both mango and avocado assuming a loss reduction of 5 percent (reducing losses from 35 percent to 30 percent in the avocado chain). In addition, a climate impact assessment showed that total emission reduction effect (= the CO_2 emission caused by the post-harvest losses) is significantly higher than the extra emission induced by installing and powering the technology.

Aggregation logistics solutions, packaging and coatings in both the mango and avocado sector are relevant technological solutions to reduce post-harvest losses but seem currently more appropriate for the export sector, in particular when considering sea freight transport.

The mango and avocado processing industry in Kenya is also largely targeting export. With export markets such as China expected to grow there is potential for investments in especially medium to large scale companies (that can meet export standards).

Considering the extent of post-harvest losses in nutrition dense food products such as Mango, Avocado and Poultry, there is a need for effective post-harvest loss reduction strategies that facilitate the adoption of sector-wide approaches whereby private and public sector organizations collaborate to address and invest in loss mitigation and loss reduction measures.

Many of the effective strategies to reduce food losses through agroprocessing and agrologistics and appropriate and suitable for high value export commodities. The domestic food system, where losses are most significant in volumes, requires customized and tailored technologies and practices that are suited to the scale, magnitude and context of small-scale farmer operations.

Addressing post-harvest losses requires collaboration of private and public partners to jointly build a conducive environment for private sector investments across the entire value chain. Such PPPs would be relevant potentially economically viable initiatives in either the mango or avocado chain. Such initiative could include groups of farmers improving the yield and quality of production, a transport and trade segment with improved market information system, a commercially-run processing facility, an integrated cold storage chain at the different levels of production including refrigerated transport, all input suppliers from nurseries to packaging, and agri-finance institutions.

1 Introduction

Although sufficient food is produced worldwide to fulfil the needs of all people, systemic bottlenecks in post-harvest supply chains hinder adequate distribution and availability of nutrient dense food products. Data discloses that at a global scale, as many as 811 million people cannot fulfill their daily dietary requirements with sufficient and nutritious foods. Currently, world hunger is on the rise, affecting 9.9 percent of people globally. According to the figures, between 2019 and 2020, the number of undernourished people is estimated to have increased by as many as 161 million, a threatening crisis driven largely by conflict, climate change, and the COVID-19 pandemic[1].

According to the FAO (2021), food and nutrition security is being affected at a global level, by both external drivers (e.g. conflict, COVID-19 pandemic and climate shocks) and internal drivers (e.g. low productivity and inefficient food supply chains). As a result the total volumes of nutrition dense foods available at local markets have reduced. This reduced availability, combined with limited income opportunities, is increasing the unaffordability and decreasing the possibility for millions of rural consumers to access healthy diets.

To comply with growing market demand, efforts and investments have often focused on improving production and productivity. Although it receives less attention, reducing and mitigating post-harvest losses, has a strong potential to contribute to improved diets, generate income opportunities for rural youth and reduce the environmental footprint of the food system.

Increasingly, information and evidence regarding post-harvest losses are providing a picture on how (and to what degree) post-harvest losses affect i) income and employment of food system stakeholders, ii) availability, affordability, accessibility and, safety of food and, iii) Resource use efficiency and the environment.

i) Post-harvest losses constitute economic losses for a variety of stakeholders starting with farmers, marketing agents, wholesalers and, retailers. Not only do these losses translate in loss in income for individual stakeholders, the national government and county governments are also affected by post-harvest losses (loss of revenues from exports and from transportation taxes).
ii) In the context of lower and middle income countries, post-harvest losses in staples and perishable nutrition dense foods severely affect the quality and quantity of food products. Post-harvest losses affect food availability (by reducing the shelf life and the time they are available in the market), affordability (through increased price fluctuation), and food safety (through possible quality deterioration and contamination)[2].
iii) Post-harvest losses generate an environmental impact not only due to the increased environmental costs of waste management but also due to the related inefficiencies in resource utilization (water, land, agricultural inputs, fuel for machinery and transport, etc.).

Effective approaches to mitigate and reduce post-harvest losses as a consequence have the potential to:

a. Improve income of supply chain actors through reducing the economic losses and through improved access to higher value markets which lead to improved market prices (Verschoor *et al.,* 2020).
b. Improve the quality and quantity of food (both staples and perishable nutrition dense foods), improve consumer prices of nutritious food, improve food safety, improve availability of food (through increased shelf-life and the ability to transport it to distant markets) In addition to contributing to enhanced dietary diversity through increased affordability and availability of fresh fruits and vegetables (Verschoor *et al.,* 2020).
c. Improve resource use efficiency, reduce waste and reduce environmental impact from agricultural production (Verschoor *et al.,* 2020).

[1] https://www.actionagainsthunger.org/world-hunger-facts-statistics
[2] (Verschoor *et al.,* 2020)

1.1 Post-harvest losses and the Kenyan food system

The population in Kenya doubled in the past 25 years and is expected to grow to 90 million in 2050 (Worldometer, 2020). A growing population increases the pressure on the food production system and the natural resources that sustain it. Agriculture is one of the key economic development sectors but already today Kenya faces structural deficits in food supply. In 2019 Kenya imported cereals for 703 USD million dollar (Euromonitor, 2020). It is expected that these imports will further increase due to increasing food demand, and will in turn increase market dependence and vulnerability to regional and international price shocks.

The agricultural production system in Kenya seems to reach its limits. Not only due to population growth but also due to increasingly occurring natural disasters such as floods, droughts, and locust. Climate change results in increasing unpredictability of agricultural growth cycles and new pests and diseases leading to severe production losses in all crops under rain-fed agriculture. In 2020 the Covid-19 pandemic shocked Kenya and showed how vulnerable the food system proved to be through food shortages and price fluctuations.

With the agricultural production growth potential reaching its limits it becomes increasingly important that the entire food system becomes more efficient and continues creating employment opportunities for rural youth. The question is how?

There are potential gains in food processing and especially in reducing post-harvest losses along the various components of food value chains. For example post-harvest losses of fruits and vegetables have been reported to be as high as 50 percent, draining incomes from the national economy (Ridolfi *et al.*, 2018) and from rural livelihoods. Kenya is facing a deficit of cereals while it is estimated that 20 percent of cereals are lost even before reaching the market. These losses translate to about 4.5 million bags of maize (12 percent of total production), which equals one-and-a-half month's consumption for the entire country. To place this in context, Kenya imports about 12 million bags of maize per year at a total cost of about USD 100 million (The conversation, 2018).

Reducing post-harvest losses will not only enhance the efficiency of the food system, reduce waste, minimize environmental damage, and make more food available; reducing post-harvest losses also offers economic opportunities for investment in innovation and appropriate technologies. It offers chances to contribute to a transition to more sustainable, resilient and circular food systems; systems that are also productive and preferably economically viable.

In this regard it is good to note that the Government of Kenya in its Big4 agenda emphasizes its support to the growth of the agro-processing industry not only to create growth and employment but also to contribute to more efficient use of food through value-addition.

1.2 Purpose of this research

This study looks into the sustainability and resilience of the Kenyan food system by focusing on food losses in the supply chains of mango, avocado and poultry. The study identifies the potential role that food processing and agri-logistics can plan to reduce these losses. Taking on a food systems approach this study:

1. Looks into post-harvest losses in the Kenyan food system and maps opportunities to make the system more efficient;
2. Opportunities for innovation, knowledge and appropriate technologies in processing and agri-logistics that help in reducing post-harvest losses will be assessed; and
3. Opportunities for (Dutch) investors and entrepreneurs in contributing to a more sustainable food system in Kenya will be explored.

By focussing on three specific agricultural products, avocado, mango and poultry the study provides an in depth assessment of the systemic drivers of post-harvest losses and the opportunities for investment in food processing and agro-logistics.

The study is expected to contribute to positive change in food system outcomes:

- **Food and nutrition outcomes** - Kenya experiences frequent food shortages. About a third of the country's population is facing food and nutrition insecurity. Improving food processing and reducing food losses and waste will increase food security;
- **Socio-economic outcomes** - 80 percent of the Kenyan population is directly dependent on agriculture as a source of food and income. Efforts to reduce post-harvest losses and emphasis on processing and value addition have the potential to increase the income of producers as well lead to economic upward in the value chains; and
- **Environmental outcomes** - Reducing food losses and waste will reduce the pressure on ("unused") land and natural resources and will mitigate negative environmental impacts of agriculture.

1.3 Overview report structure

Chapter two of this report provides a characterization of the Kenyan food system, with emphasis on food losses. In this chapter attention is given to the drivers and dynamics underlying the occurring losses and their relation to food system outcomes.

Chapter three contains three separate rapid sector assessments that look into the critical loss points in the mango (chapter 3.1), avocado (chapter 3.3) and poultry supply chains (chapter 3.5) respectively. In the identification of key leverage points to address food losses a distinction is made between shallow, intermediate and deep leverage points. It is argued that effective mitigation of food losses requires an integrated food system approach bundling multiple leverage points into a customized sector wide strategies.

Chapter four describes the underlying reasoning and factors that were taken into consideration to identify viable business opportunities to reduce losses through food processing and agri-logistics.

Chapter five provides and in depth analysis of the identified business opportunities highlighting the importance to consider appropriate and adequate scale of technologies, the trade-offs and their costs and benefits.

Chapter six, summarizes the main conclusions and recommendations of the report.

2 Characterization of the Kenyan food system

This chapter describes the main components and focusses on the dynamics, behaviors and drivers that shape the contours of the Kenyan food system. Taking on a systems perspective the chapter provides insights into the root causes and drivers of post-harvest losses in order to guide the identification of opportunities for investment and the identification of specific leverage points to reduce losses.

> **"Millions of (Kenyan) households depend on agriculture for income and food security, therefore the country's social stability and economic growth depends on enabling these people to contribute to the economy and offering them better food security. This is the mark of successful inclusive agricultural transformation"**
>
> (Agricultural Sector Transformation and Growth Strategy 2019 – 2029)

More than 80 percent of the Kenyan population is directly dependent on agriculture as a source of food and income (FAO, 2020). In addition, the agricultural sector is responsible for 65 percent of export earnings. Kenya's agricultural sector has improved significantly in recent decades in terms of production, productivity and growing orientation towards the export market. Nevertheless, the successes achieved have not yet led to structural improvement with regard to food security, nutrition and poverty alleviation in Kenya itself.

Over the last two decades, significant progress has been made in meeting the kilocalorie requirements of Kenya's rapidly growing population. Nevertheless, statistics point to an increase in malnutrition and note a sharp increase in overnutrition over the past 30 years driven by changing consumption patterns in which vegetables, fruits and high quality proteins are less prominent (Rampa & Dekeyser, 2020).

Agricultural production and productivity have grown significantly in the last 20 years, yet large amounts of the agricultural products are lost before they reach the market or consumers. These losses affect both small-scale and commercial producers, as well as middlemen, suppliers, distributors, traders, exporters, wholesalers and consumers.

These losses not only affect the economic income of stakeholders but they also affect the local availability and affordability of nutritious and essential food products. In addition, these losses are related to inefficiencies that have a negative impact from both an environmental and an economic point of view. Post-harvest losses of perishable and nutrition dense agricultural products such as fruits and vegetables and fresh animal products of over 40 percent are common.

2.1 Food System typologies

There are different modalities in which food is produced, supplied, processed, marketed and consumed in Kenya. These modalities range from small scale subsistence food supply systems to regulated, formal food supply systems geared towards the export of high value agricultural commodities for global consumers. For the purpose of this research, two of the prevailing and characteristic food supply systems have been identified based on the food system typologies form the food system dashboard (2020)[3]:

[3] https://foodsystemsdashboard.org/

1. Rural traditional informal and expanding food supply systems

Low external input food supply systems where small-scale farmers dominate agricultural production. Production is predominantly geared towards staple crops (cereals and pulses) with some (perennial) cash crops that do not require large extensions of land. Production destined for market is traded through informal networks reaching rural and urban consumers. Medium to large scale farms commercial farms are increasing in numbers. Farmers are progressively making use of agricultural inputs. Supply chains are largely governed by informal brokers, with diverse distribution channels. Storage infrastructure for key staples is increasingly present. Losses in fresh, perishable and, nutrition dense food products remains rampant as a result of inadequate management, limited transport infrastructure a lack of temperature management and, cold chains. Food quality and food safety standards are not widely enforced in the informal sector. Although the largest volumes of food products are still traded through informal markets, urban consumers increasingly purchase their foods through formal networks, supermarkets and fast-food outlets.

2. Emerging and diversifying food supply systems

Food production is still dominated by large numbers of small-scale farms but the prominence of commercially oriented medium- and large-scale farms is increasing. Use of agricultural inputs is common. Formal supply chains for fresh foods (fruits, vegetables and animal source foods) are growing and urban markets increasingly source dry and fresh foods through from rural areas, in addition to imports. Supermarkets are growing in number in larger cities, attracting growing numbers of consumers who are demanding different food products and willing to pay premium prices for them. Food safety regulations and standards are present and are predominantly enforced in the formal market systems. Commercial farms increasingly orient their production practices towards high value markets, including the export market. Coordinated and integrated supply chains ensure quality of food products is maintained during transport and storage. Processing and value addition increasingly takes place in country through organized and formal networks of food system stakeholders.

2.1.1 Post-harvest losses in relation to food system typologies

The rural and traditional informal and expanding food system typology is the most common in Kenya and responsible for the production of the largest volumes of food products. In the case of Avocado, Mango and Poultry over 80 percent of volumes of these food products are generated in the rural tradition informal and expanding food system. As mentioned, these systems are characterized by small-scale farming practices that rely on the seasonal rains for production. Small-scale farmers typically have very limited access to storage and processing facilities. As a result, they tend to sell primary produce when seasonal production is at its highest and prices are low. Small scale farmers sell and distribute their produce through informal networks where marketing agents play a key role between rural smallholder producers and rural wholesalers, urban wholesalers, local traders, supermarkets, shop-owners and street sellers (Rampa & Dekeyser., 2020). As such they have a vital function in the food production and distribution interface.

2.2 Food System stakeholders

A large number of the stakeholders that interact on a formal and informal basis have been mentioned in the descriptions above. Table 1 provides an overview of key stakeholders in the Kenyan agri-food system describing their specific roles and activities.

Table 1 *Overview of roles and functions of key food system stakeholders*

Actor	Roles	Key characteristics and activities
Agricultural input suppliers	Sale and distribution of agricultural inputs (seeds, seedlings, planting materials, chicks)	A range of agricultural input suppliers exists varying from nursery operators, to agro-vets, to shopkeepers selling agrochemicals. In many cases these stakeholders additionally provide front-line extension services to farmers on how to best utilize the inputs they have supplied.
Agricultural Producers	Farmers responsible for on-farm management and operations and generation of market linkages	Mostly small scale farming operations with some more commercially oriented farms. Farm management and activities are largely done by smallholder farming family or to a limited degree by hired wage-laborers. The majority of farmers maintains a functional relationship with marketing agents, buyers and traders who support with investment credit, harvesting and transportation, distribution and marketing of primary produce.
Producer organization	Aggregate smallholder produce and support market linkage	Horizontal integration of individual producers into producer organizations that assists in linking farmers with markets and support in negotiating better prices for agricultural produce and at times reduced prices for agricultural inputs.
Marketing agents	Linking producers with market and supporting harvesting and post-harvest management	These stakeholders provide a fundamental service and marketing channels for a vast number of small-scale farmers who generate small volumes of agricultural produce that is too expensive to market individually. Marketing agents often support producers with loans or anticipated payments. In most cases marketing agents tend to cover the cost of harvesting, collection and transport to the market. Marketing agents link agricultural produce to the domestic market, small scale processors and to exporters. It is estimated that 95 percent of the marketing agents, traders, brokers are young men (Imani 2019).
Transporters	Transportation of agricultural produce to buying centres	Transportation and distribution of raw farm produce from the farmgate is done both in large and small scale. Main forms of transport are trucks, "Pick-ups", motorbikes and pull carts. The transportation cost varies according to distance, quantity and fuel charges. Inadequate packaging and lack of temperature control during transportation severely impacts food losses. At times marketing agents also fulfil a role as transporters
Wholesalers and retailers	Purchase of raw agricultural produce, sorting, grading and trade in domestic market (urban and rural)	These two groups dominate the domestic informal and formal marketing channels. The wholesalers purchase large quantities of agricultural produce and then sell this to other traders. Most of them have access to market information and the financial capacity to purchase bulky commodities. Retailers mostly run small- to medium-scale businesses in various markets across the country. They purchase fruits from wholesalers or producers in small volumes and then provide them for end consumers. Supermarkets are increasingly positioning themselves in the retail sector and establishing relations with marketing agents, producer organizations and traders.
Exporters	Transporting, sorting, cleaning, grading, packaging, branding and selling agricultural products destined for regional and international markets	Small and medium scale exporters are numerous, while there are only a limited number of large scale exporters operating in Kenya. Most exporters work with multiple products and multiple destination markets. Exporters work in close collaboration with producer organizations, marketing agents to aggregate volumes and quality required for export. Exporters have access to modern technologies for postharvest management, handling, cold storage, packing and transportation which significantly reduces food loss in export chains.

Actor	Roles	Key characteristics and activities
Processors	Processing and adding value to raw agricultural products	There are small-scale processing activities driven by SME's and large scale commercial processing activities driven by private companies with industrial infrastructure. Sourcing adequate volumes of raw agricultural products, of the right quality and in compliance with food safety norms can be challenging for these enterprises.
Ministry of Agriculture Livestock and Fisheries	National authority for the agri-food sector	Oversees and coordinates overall implementation of agricultural policies and strategies
County government	Sector coordination and support services at county level	Coordinate sector transformation strategy, extension and input support Collect revenues from traders, transporters and processors.
Regulators and service providers	Registration, certification and inspection of agricultural enterprises and exports	**Agriculture and Food Authority (AFA) –** regulation, development and promotion of scheduled crops value chains for increased economic growth. Involved with market research and product development, technical and advisory services. **Kenya Plan Health Inspectorate Service (KEPHIS)** - certification of agricultural input dealers, inspection and diagnosis of planting material. Provides certificates on food quality and food safety, facilitates market access for agricultural produce for export, facilitates imports of new varieties, offers advisory services on pest and disease management. **Horticultural Crops Directorate (HCD)** -registration of industry dealers; promotion and development of horticultural crops; capacity building of industry stakeholders; regulation of players through inspections especially on export produce. **Pest Control Products Board (PCPB)** -regulates importation, exportation, manufacture, distribution and use of products for the control of pests. **Fresh Produce Exporters' Association of Kenya (FPEAK)** trade Association representing growers, exporters and service providers in the horticulture industry. Coordinating the horticulture export industry.
Agri-finance providers	Provision of financial services, credits and loans	**SACCOs, Banks, Farmers associations** providing access to financial services and agri-finance.
Research institutions	Generation and validation of agricultural knowledge and innovation	**Kenyan agricultural and livestock research organization (KALRO)** Research and dissemination of agricultural technologies and innovations. **Agricultural universities:** Egerton University, Jomo Kenyatta University of Agriculture and Technology, University of Nairobi.

Stakeholder collaboration, and orchestration of supply chain activities is an essential element of effective, inclusive and sustainable food systems. Effective transformation of the Kenyan agri-food sector requires concerted efforts and bundled approaches whereby private and public sector organizations collaborate and invest to make the food system more sustainable, inclusive and efficient.

2.3 Socio-economic drivers of the Kenyan food system

The following subchapter provides an overview into key socio-economic drivers that affect the behavior of the Kenyan food systems. It describes how different factors such as market trends, demographic trends and consumer behavior affect the food system and the agri-food sector. In addition, it provides an overview of policies and strategies that support agro-economic development, agro-processing and FLW mitigation. Taking this larger context into account provides an improved understanding of the root causes and systemic conditions that contribute to food losses.

2.3.1 Domestic, regional and international agri-food markets

Kenya is considered one of the economic powerhouses of eastern Africa. The agri-food system is one of the fundamental pillars of the national economy. The agricultural sector has seen steady growth over the last 10 years (Kenya National Bureau of Statistics, 2020). The agri-food system contributes 34 percent of the total national GDP and 65 percent of all export related earnings (World Bank, 2020). The agri-food sector is largely informal. The informal sector generates more than 80 percent of employment opportunities in Kenya, and the agri-food sector takes up a good proportion of this percentage (Kenyan National Bureau of Statistics, 2020).

Kenya's national economy has enjoyed considerable growth over the last 15 years (World Bank, 2020) Thanks to its stable political climate, its strategic geographical location, sustained economic growth and social development Kenya has witnessed a favorable climate for foreign direct investment (Rampa & Dekeyser., 2020). Export-oriented horticulture and floriculture have spearheaded the development of the agri-food system but these are dominated by a limited number of high-quality, export-oriented products that are cultivated by a limited number of commercially oriented large-scale farms that rely on capital investment (Rampa & Dekeyser., 2020). The contribution of the agricultural sector's to economic growth has weakened over the last years as climate change and the COVID pandemic have created perturbances that have uncovered the structural vulnerability of the agri-food system, affecting its relative growth rates (World Bank, 2020; KNBS, 2020).

Kenya is strong in production of raw agricultural products. Processing and manufacturing of agri-food products is considered an emerging market opportunity.

Table 2 provides an overview of different activities in the agri-food system and their relative contribution to Kenya's GDP. It illustrates how growing of crops is a main contributor to GDP and how support activities such as manufacturing and agroprocessing, wholesale and retail, transport and storage still remain small contributors to GDP at the moment. At national and county levels a variety of policies and investment strategies are in place to continue developing the Kenyan agri-food sector, both domestically and internationally.

Table 2 *Percentage contribution to GDP by activity 2016-2020 (source KNBS- Economic survey 2021)*

Subsector/ Activity	2016	2017	2018	2019	2020
Total Agriculture, forestry and fishing	**20.0**	**20.9**	**20.3**	**21.2**	**23.0**
Growing of crops	14.1	15.2	14.5	125.1	16.6
Support activities to agriculture	0.2	0.2	0.2	0.2	0.2
Manufacture of food, beverages and tobacco	5.1	5.0	4.8	4.5	4.4
Wholesale and retail	8.3	8.4	8.2	8.2	8.1
Transportation and storage	10.2	10.2	11.3	11.7	10.8

Kenya has the potential to place itself as a leading agricultural producer in the regional market. The African continent has been the leading destination for Kenya's exports. In 2019 these exports accounted for more than one third of the total exports, of which two thirds are channelled to partner countries within the eastern Africa community (KNBS, 2020). The potential of regional trade is still

constrained by deficient road infrastructure and inhibiting rules and legislations that have not enabled full liberalization of regional markets and trade.

Table 3 *Principal Kenyan exports 2015 - 2019. Source KNBS Economic Survey 2020*

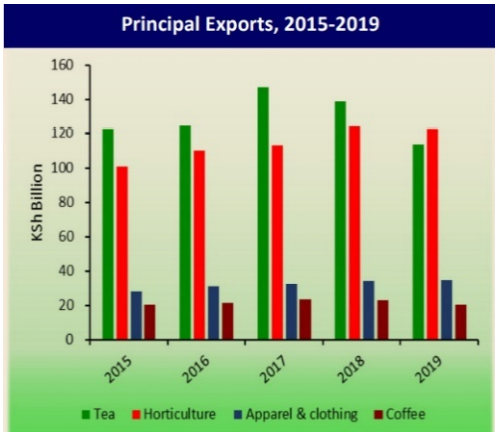

Table 3 illustrates the contribution of four of Kenya's principal export sectors (tea, coffee, horticulture, apparel and clothing to the National economy. The table shows how the horticultural sector (red bars) has grown over the years and has recently even surpassed from the tea sector in terms of value exported.

Kenya's agricultural sector is increasingly positioning itself in the global agri-food system. Agricultural exports have a series of key destination markets, namely Pakistan, the USA, Europe and the UK (KNBS, 2020) Within Europe, the Netherlands, Germany and the UK are the largest markets. Trade relations with China are growing steadily. In 2019, income derived from exports in the horticultural sector overtook other key exports, although the respective value of horticultural exports declined by 5.9 percent (KNBS, 2020).

2.3.2 Employment and rural livelihoods and economic development

Kenya's agri-food system accounts for employment of approximately 54 percent of the total working population (World Bank, 2020) although it is assumed that indirectly more than 80 percent of the total population derives their livelihood from the agri-food system. Micro and small sized farmers account for the largest proportion of agricultural producers (Benni *et al.*, 2020). Approximately 87 percent of Kenyan farmers have access to less than 2ha of land, of which 67 percent cultivate less than 1ha (World Bank, 2020).

Post-harvest value addition in the agricultural sector is growing but still limited in scale. Most smallholder farms do not have access to storage facilities. In addition to seasonality, this impacts the quantity and quality of raw materials that are available for value addition and agro-processing (Agricultural Sector Transformation Strategy, 2019).

The agricultural sector plays a fundamental role in reducing poverty in Kenya. A comparison on poverty rates using national household surveys from 2005 and 2015, shows that households benefitted the most from the agriculture sector growth compared to growth in other sectors of the economy: a decrease in poverty rate of 2.2 percentage points (World Bank, 2108).

Livelihoods of people within the agricultural sector are volatile and extremely vulnerable. Shocks and perturbances in the agriculture sector have a large impact on poverty. Food losses in the agricultural sector also have a large impact on smallholder producers' livelihoods.

Regardless of the mentioned progress, in 2021 over 7.8 million people in Kenya are living in extreme poverty (less than 1.90 U.S. dollars a day); of which 6.6 million in rural areas. Overall, the poverty incidence declined in recent years but at a lower rate in urban areas compared to rural areas[4].

Agricultural production is dominated, in volumes, by smallholder farming families. Although they predominantly derive their livelihoods from agricultural activities they are often vulnerable to environmental shocks, market price dynamics and furthermore are highly reliant on the services of marketing agents and traders. These conditions tend to create a situation whereby smallholder

[4] Kenya: people in extreme poverty by area 2016-2021 | Statista

farming families are capable to upkeep their livelihoods in good years but remain highly vulnerable to external factors and are often unable to emerge out of traditional and informal production systems.

According to a recent diagnosis by the world bank approximately half of Kenya's population is younger than 18. Nine million individuals are expected to enter the labour market between 2015 and 2025. This means that Kenya will need to create an average of 900,000 jobs every year (World Bank, 2020). The agribusiness sector has potential to create off-farm job opportunities for young men and women.

2.3.3 Food security and nutrition

According to an analysis by FAO, Kenya has taken great steps in improving food security over the last 20 years. Wasting, stunting, anemia, and the Global Hunger Index score declined during this period (Rampa & Dekeyser, 2020). In addition, the food deficit[5] in Kenya was reduced from 209 kcal per person per day in 1990 to 135 kcal per person per day in 2016 (World Bank, 2020). In contrast there are also indications that the prevalence of undernourishment has increased, from 22.3 percent in 2013 (10 million Kenyans) to 29.4 percent in 2017 (14.7 million Kenyans). Approximately 30 percent of households regularly lack enough money to buy food. In addition there is evidence that rural households suffer from lower dietary diversity and higher micronutrient deficiencies including iron and Vitamin A, when compared to the national averages (Agricultural sector transformation strategy, 2019).

Key drivers of food insecurity include poverty (affecting food access), food safety issues, low dietary diversity and protein quality, insufficient supply of fresh food (affecting food availability) lack of rural infrastructure (roads and infrastructure, irrigation) and little access to finance for smallholder farmers (GFSI, 2021). A significant proportion of Kenyans does not consume the recommended amounts of nutritious-dense foods such as fresh fruits and vegetables (Pengpid & Peltzer., 2018). Fresh fruits and vegetables, due to their perishable nature, encounter loss rates of over 30 percent of total production. Mitigating and reducing these losses will increase the availability and the affordability of these valuable food products.

2.3.4 Changing diets and consumer preferences

As Kenya witnesses a rapidly increasing urban population and changing dietary preferences, new modes of food production, distribution and consumption must warrant access to, availability and affordability of nutritious and safe food. Perishable, nutrition dense food products such as fresh fruits and vegetables and protein rich foods require special attention. Between 1990 and 2017, the percentage of the Kenyan population suffering from overweight has almost doubled from 13.2 to 25.5 percent (FAO, 2019).

Kenya's economic growth, population growth and urbanization trends are structurally reshaping the dynamics of the food system. Demand for food is exponentially increasing along with changing consumer preferences and dietary changes that are taking place. With population numbers expecting to double by 2050, demand for cheap, healthy and, safe food products in both urban and rural areas is expected to increase threefold (Rampa & Dekeyser., 2020).

There is evidence of a growing middle class in Kenya, living in larger cities with access to higher disposable incomes. This population group is changing their dietary habits. On the one hand there is an increasing demand for fresh, perishable, nutrition dense, high-quality foods. On the other hand there is also a growing demand for processed foods and fast-foods, evidenced by the exponential growth of fast food chains and consumer oriented food-products. From a different perspective, urban sprawl is also causing an increase of informal urban settlements composed of poor households who are looking for affordable staple foods (World Bank, 2020).

[5] Food deficit is an indicator which measures the degree and magnitude of deficit in kcal required to achieve full caloric security.

By 2039 it is expected that Kenya will have a population of 81 million (FAO, 2021). It is forecast that by 2050 the urban population will grow to more than 42 million people, constituting approximately 44 percent of the total population (IFAD, 2016). These increases are expected to triple the domestic demand for cereals and staple foods (World Bank, 2020).

Growing consumer concerns regarding food safety are putting pressure on smallholder farmers who struggle to comply with regulations, volumes and consistency of product quality to access these growing high-end markets and comply with consumer demands (Rampa & Dekeyser., 2020). Currently, traditional and informal market outlets are still accountable for more than 60 percent of food related transactions.

Strategies to tackle food loss and waste can contribute significantly in meeting the growing demand of safe and nutritious food in Kenya. Taking the examples of fresh fruits and vegetables as reference, it is assumed that more than 30 percent of the harvest is lost before it reaches the end consumer. Reducing these losses will directly increase the availability and the affordability of these nutrient dense foods in the local market.

2.4 Environmental drivers of the Kenyan food system

Land use change, deforestation and expansion of the agricultural frontier have significantly modified the agri-foodscape and related environmental conditions over the last decades (Rampa & Dekeyser., 2020). Habitat loss and land degradation are putting high pressure on both agricultural potential and non-renewable natural resources. Agricultural land has rapidly diminished which means that any projected increase in agricultural production must be sustained by intensification and increased productivity. This proves difficult considering that over the last decades, yields of major cereals have stagnated regardless of increased usage of agrochemicals and fertilizers (Rampa & Dekeyser., 2020).

Agricultural activities occupy more than half of Kenya's land surface although only 18 percent of the country's total land surface receives sufficient rainfall to make it suitable for agricultural production. Only 2 percent of agricultural land has access to irrigation water, making agricultural highly dependent on reliable and regular rainfall. Regardless, the agricultural sector utilizes approximately 60 percent of all the water available in Kenya (World Bank, 2020). Droughts are becoming a serious environmental risk for the agricultural sector, even more so considering that the largest majority of producers do not have access to irrigation (Rampa & Dekeyser., 2020).

Changes in temperature and rainfall, together with extreme weather events are becoming the norm in Kenya. Erratic rainfall patterns, and floods, droughts and other climate related disasters (for example the prevalence of pests and diseases) have a severe impact on the food system, and on agricultural productivity and will increasingly continue to do so in the future (Rampa & Dekeyser., 2020; World Bank, 2020; Advance Consulting, 2019). Without adaptation and mitigation strategies, the effect of increased temperatures on agricultural production will have severe impacts on people's livelihoods, Kenya's food and nutrition security and the national economy.

The limiting environmental conditions threaten agricultural production and hence the food security of Kenya, and emphasize the need to become more efficient in the production of food. Strategies to address post-harvest losses indirectly contribute to more efficient production system and food system resilience and its capacity to cope with climate variability.

The agricultural sector is also increasingly being affected by pests and diseases. The recent locust plague is a result of environmental factors that led to the prolific breeding and distribution of these insects (World Bank, 2020). Moreover production of perishable fruits and vegetables has been struggling with pest infestations that at times have restricted exports severely.

Stagnating yields are causing farmers to apply large amounts of agro inputs on their land which in turn has adverse effects on the environment and soil conditions.

More than half of Kenya's total land coverage is utilized for agricultural activities (World Bank, 2020). Agricultural expansion and population expansion have significantly contributed to the decrease in area of forested land. In the last 30 years, the agricultural frontier has expanded, adding an additional 8000 km^2 of land to agricultural activities (Rampa & Dekeyser., 2020). Availability of productive land is increasingly diminishing leading to high pressure on natural resources and land.

2.5 Food system policies addressing FLW, agroprocessing and agrologistics

As one of the structural cornerstones of the Kenyan economy, the agricultural sector directly and indirectly supports the livelihoods of a large portion of the Kenyan population. Kenya's food system is complex, diverse and dynamic. A large number of food system stakeholders, public, private, non-governmental and parastatals interact and take up specific roles and functions in this Food System (Rampa & Dekeyser., 2020; D'Alessandro *et al.*, 2015). Concurrently a large number of national policies are specifically geared towards structural development of the agri-food system. There is currently no national policy explicitly addressing post-harvest losses.

Over the last 10 years the largest majority of agricultural policies and public investments have been characterized by a strong state presence and control of produce and input prices (in particular for food security crops such as maize and beans). Main emphasis has been on stimulating production and productivity (Rampa & Dekeyser., 2020; D'Alessandro *et al.*, 2015). Gradually the trend is moving towards the promotion of private sector involvement and public-private investments to drive agricultural development and sector transformation. In addition the role of the County-level governments has gained prominence in promoting food and nutrition security and coordination of investments and partnerships for sector development.

Since 2010 Kenya has devolved a large part of responsibilities, attributes and competences related to the agri-food sector towards elected county level authorities (Rampa & Dekeyser., 2020). The national government remains focal point for coordination and policy formulation. County governments have been delegated a series of responsibilities such as: extension and advisory services, and infrastructure development. Resources for agriculture are mobilized both from the National government and from County-level funds. In practice country government often invest larger proportions of their budget in agriculture related topics in comparison to the national government (Rampa & Dekeyser., 2020). County governments are increasingly implementing agricultural sector development programs and are considering investments in post-harvest management, aggregation and agroprocessing within strategic supply chains.

At a national level a number of key policies and strategies guide investments in agricultural development:

Kenya's Vision 2030 strategy was launched in 2008. The strategy positions agricultural development as a structural pathway to reduce poverty and enhance food and nutrition security whilst contributing to a robust national economy. The strategy conceptualizes agricultural development as a fundamental pilar for inclusive economic growth. The strategy strives towards: increased production of food, reduced food prices, establishment of food safety regulations and increased value addition through agro-processing. The strategy formulates the following food security (food system) objectives:

- 34 percent increase in average daily income of farmers
- 27 percent reduction in malnutrition among children under 5 years
- Creation of 1000 Agro-processing SME's and 600,000 new jobs
- 50 percent reduction in the number of food insecure Kenyans
- 48 percent increase in agriculture sector contribution to GDP
- 47 percent reduction in the costs of food as a percentage of income.

Within the **Government's Third medium Term Plan (MTP) 2018-2022** particular emphasis is given to promoting irrigation, investments in storage facilities and conveyance infrastructure (Third

medium term plan, 2018 -2022) with the central underlying objective of creating employment opportunities, targeting 1.3 million new jobs per year. The plan envisions employment opportunities within the manufacturing sector considering that at least 50 percent value should be added to raw materials derived from agricultural production.

In parallel **Kenya's big four agenda, launched in 2017** focusses on four key pillars: food security, affordable housing, manufacturing and universal health coverage. The agenda focusses on economic growth and the creation of employment opportunities by means of public and private investments in a series of subsectors including agroprocessing, service provision and value addition in the agri-food sector.

Kenya's **Agriculture Sector Transformation and Growth Strategy (2019-2029)**, builds on Kenya's big four agenda, the Malabo declaration, SDG's commitments and the African Union's Agenda. This strategy has a twofold approach to strengthening large scale commercial farming as well as smallholder productivity. The strategy focusses on production, productivity increases and post-harvest value addition. Strategic Public Private partnerships and investments will spearhead the development of Kenya's agri-food system. The strategy considers employment generation for youth as a priority for sector transformation.

The Kenya Youth Agribusiness Strategy 2018- 2022, implemented by the Ministry of Agriculture Livestock and Fisheries (MoALF), aims to increase employment opportunities and support youth participation in agribusiness. The strategy focusses on youth entrepreneurship, inclusive agri-finance instruments, agroprocessing and in-country value addition of agricultural products.

There is no specific national policy or strategy related to post-harvest loss reduction. **The National Sustainable Waste Management Policy**, launched in 2018, obliges Kenyan businesses to process their waste sustainably[6]. Currently this policy is not being implemented or enforced.

At a regional level, the signatories of **The Malabo Declaration**, including Kenya, have committed to reducing the current levels of post-harvest losses by fifty percent by the year 2025. This has not been translated to a national post-harvest loss reduction strategy.

In the absence of a National policy that targets post-harvest loss reduction, there are little incentives, norms and regulations or other mechanisms that support stakeholders to tackle this issue structurally. Policies that target increased production and productivity would be complemented by incentives that would encourage producers, transporters and traders to address post-harvest losses.

Effective policies creating incentives to invest in post-harvest loss reduction have a potential in improving availability, accessibility and affordability of nutritious dense foods for local consumers and additionally improving the income of large numbers of rural householders who depend on small-scale agricultural activities to sustain their families and livelihoods. Examples of such policies and regulations are regulations for the transport and handling of fresh produce; public private partnerships to invest in cold chain technologies and digital innovations; promotion of social inclusiveness by creating rural employment; availability of safe and affordable fresh fruits and vegetables; government procurement instruments that purchase fresh fruits and vegetables for schools, hospitals, public administrative buildings etc.

[6] http://www.environment.go.ke/wp-content/uploads/2019/01/Waste-Policy-DISCUSSION-DRAFT-10-2-18.pdf

2.6 Key leverage points to address food losses

The food system analysis has highlighted that there are numerous interrelated food system elements that influence food losses in complex manners that are both geography specific and supply chain specific. Food losses manifest at various stages of the supply chain and are often caused by specific practices that occur in a different stage of the supply chain.

Although there are existing technologies and practices that have proven to be effective in reducing post-harvest losses, the it is relevant to simultaneously address the behavior and dynamics of the system that directly and indirectly affect losses.

This report identifies a variety of leverage points (places to intervene in the complex food systems) to bring about the desired changes which contribute to a reduction of post-harvest losses, improved access, affordability and availability of nutrition dense foods; the generation of off farm employment opportunities for rural youth in agroprocessing and service provision and improved efficiency in resource use (land, water, labor and other agricultural inputs).

The study has identified a variety of leverage points which differ in scale, scope and focus. This research identifies shallow, intermediate and deep leverage points for mitigating and reducing post-harvest losses, based on the characterization of leverage points, suggested by Donella Meadows, and Abson (2016).

The 'shallow' leverage points consider interventions that are relatively easy to implement, and that address the problem but do not modify the actual functioning of the system. For the case of mango, avocado and poultry, these shallow leverage points are, amongst others efforts to improve good agricultural practices and investments in low-costs temperature controlled storage facilities.

'Deep' leverage points in contrast, consider systemic change processes that might be more difficult to alter but potentially result in transformational change. These leverage points include policy changes and interventions that change the behavioral practices and relations between supply chain stakeholders.

The following subchapter lists a number of the identified leverage points, starting with shallow leverage points and progressively moving towards more deep leverage points. Each leverage point has been assigned a specific number, which in turn is used to visualize the location of respective leverage points in the food system framework (Van Berkum *et al.*, 2018) – see figure 1.

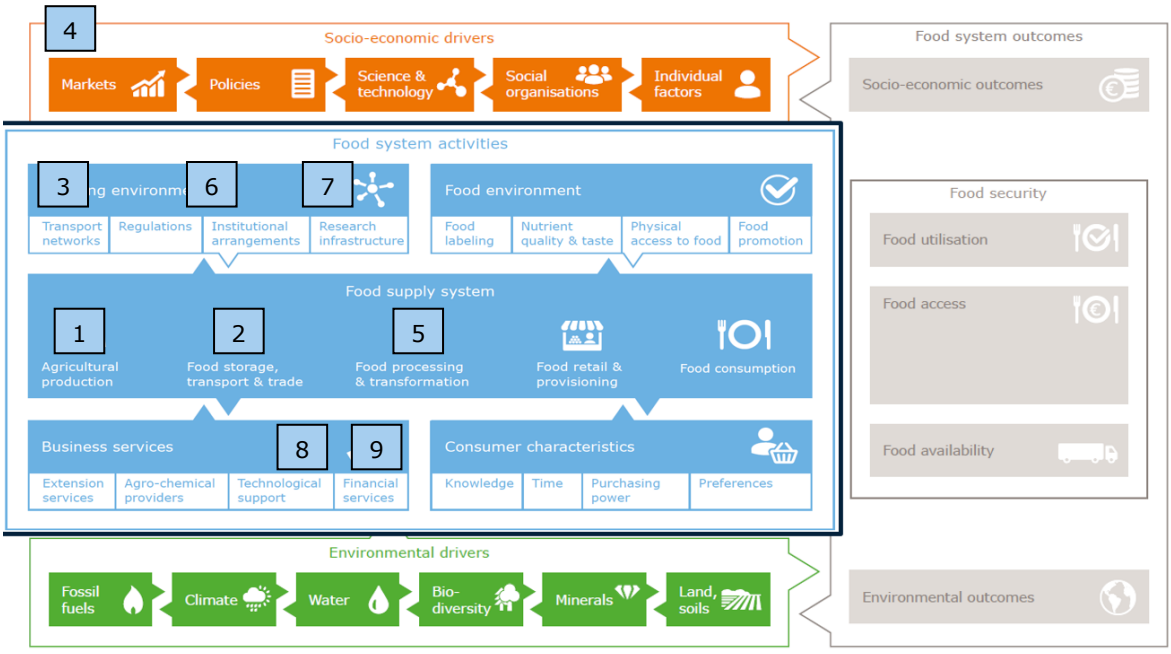

Figure 1 *Leverage points mapped out on Van Berkum, food system framework*

2.6.1 Shallow leverage points

1. Good Agricultural Practices
production practices and post-harvest handling practices, including the utilization of improved varieties, seeds, integrated pest management, etc.

2. Temperature controlled storage facilities
The agricultural sector is further affected by the lack of cold storage facilities. Especially smallholder producers are constrained in accessing markets as they need to invest in logistical and transaction costs to transport their small volumes of produce to the market (Imani 2019) (World Bank, 2018) (World Bank, 2020) (Wangu, 2020). Low-tec and small-scale cooling mechanisms can be very cost effective for first mile cooling.

2.6.2 Intermediate leverage points

3. Rural transport infrastructure
The lack of and poor quality of transport infrastructure in rural farming areas generates significant challenges, and additional costs, for smallholders and rural producers to access the market with their farm produce. According to a study by the World Bank, approximately 30 percent of road infrastructure requires rehabilitation or reconstruction (World Bank, 2019).

4. Market access
Smallholder farmers' access to markets is often constrained by a series of factors, all of which affect post-harvest food losses. The quality of rural infrastructure mentioned above generates additional transport and logistical costs. Horizontal and vertical market integration is often restricted, limiting coordination, access to market information and logistical efficiencies. Stringent quality regulations for export crops further constrain possibilities for smallholders to integrate in the export market due to the amount of investment required and the need to supply stable volumes of high quality produce. The domestic market is highly informal and regulated through informal networks. Real time information on market demand and product availability is not readily available.

5. Agro-processing and value addition
While agricultural production and productivity dominate the agricultural economy, agro-processing and value-addition has not taken a prominent role. According to a diagnosis from the World Bank, only a limited number of private companies are involved in processing as a result of a series of constraints, the principal being: limited ability to secure stable volumes and quality of raw materials (World Bank, 2019). The emerging companies that are investing in value addition are creating diversified market and creating value for products that were previously not considered of value in the market (e.g. such as the avocado oil processing company Olivado will be referred to in detail in chapter 3 and chapter 5).

2.6.3 Deep leverage points

6. Enabling environment and investments in sustainable and inclusive food systems
Efforts to increase productivity have focused on improving production practices, access to inputs, agricultural technologies and the promotion of export oriented agriculture (World Bank 2020). Public investment in improving post-harvest management and storage has targeted staple crops but little efforts were made to improve post-harvest management of nutrition-dense foods such as fresh fruits and vegetables destined for the domestic market. On the other hand great progress has been made to strengthen the positioning of the export agricultural sector through a series of public private partnerships and increased collaboration throughout the sector targeting applied research, inclusive governance, quality assurance and sector regulations.

7. Lack of in data on food losses to influence decision makers and policy priorities
There is a general lack of field validated data on food loss and waste in Kenya and a lack of detailed insights of food loss and waste profiles for different supply chains and agricultural products. As a result there is no evidence on the magnitude of the problem, it's impact of the food system and its

stakeholders, and major bottlenecks affecting losses. Without concrete evidence and information it is difficult for policymakers to address the issue and establish strategies or policies to address the issue (Xue, L *et al.*, 2021).

8. Market transparency and accountability

The value of agriculture products is primarily related to volumes and quantities. Smallholder producers and marketing agents show little concerns for post-harvest management practices. Agricultural produce is often transported and handled in bulk, in bags or sacks or small cages, increasing the possibilities that products will be damaged, bruised or even perish from suffocation (in the case of live animals). Transporters and marketing agents often calculate potential risks of food losses into the price they offer at the farmgate. Agri-entrepreneurs geared towards the export market consider post-harvest management as integral part of their operation to guarantee product quality and supply chain efficiency. Incurring extra costs for post-harvest management is feasible for exporters who obtain premium prices but not feasible for smallholder farmers who have small volumes of produce in rural locations far away from the consumers and markets they cater for. Traceability mechanisms have proven to provide more open access to market information, due diligence, and also have the potential to generate realistic sector level information on post-harvest losses.

9. Agri-finance

Even though Kenya is known for its vibrant markets and uptake of financial technologies only 4 percent of financial loans are for agri-finance (World Bank, 2019). Currently most farmers that access finance use these resources to purchase agricultural inputs, invest in mechanization or irrigation with the key objective to boost production and productivity. Post-harvest management and post-harvest value addition have not received the attention of the agri-finance sector. Designing customized financial mechanisms in support of effective storage, post-harvest management and agro-processing has the potential to reduce losses, improve food availability and affordability, generate sources of employment and add value to primary agricultural products.

3 Rapid sector assessments in relation to food losses and waste

3.1 An overview of the mango sector

3.1.1 Markets and policies

The mango sector is a key priority for the Kenyan horticultural sector and is considered to hold the potential to contribute to sustainable food system outcomes and the agricultural components contemplated in Kenya's Big Four Agenda.

Kenyan produced mangoes are in demand locally, regionally and internationally. Although the export market has been steadily growing; the largest volumes of mangos are destined for the local market. (Xcom Africa, 2014; ITC, 2014; Owuor, 2020). On a global scale, Kenya ranks 15th in terms of mango production and accounted for 1,5 percent of global production in 2017. Kenya is among the leading producers of mango in the east African region (Imani, 2019).

The total land expansion used for mango cultivation has been increasing over the years. Latest reports indicate that mango is grown on 49,098 hectares producing 779,147 metric tonnes of mangoes valued at KSH 11.9 billion which is about 21 percent of the total value of fruits produced in Kenya[7]. Production growth in the last decade is attributed predominantly to an increase in the area under production and moderate increases in yields (Imani, 2019)

Table 4 highlights specific information for the case of Makueni, Machakos and Embu, the three counties we have focused on in this analysis.

Table 4 *Data on the production of mangoes in Machakos, Makueni and Embu (Source Owuor, 2020 based on HCD, 2018*

County	Area[8] 2016	Prod 2016	Value 2016 (KSH)	Area 2017	Prod 2017	Value 2017	Area 2018	Prod 2018	Value 2018
Machakos	6,387	168,552	2,764,574,500.00	5,518.00	169,345.00	2,723,955,000.00	6,528.00	166,402.00	2,780,170,000.00
Makueni	12,422	225,300	3,617,524,000.00	6,827.00	77,223.00	1,206,663,000.00	12,944.00	120,888.25	2,000,800,000.00
Embu	850	14,450	332,000,000.00	947	14,733.00	215,040,000.00	790.00	9,631.00	145,662,500.00
Total	*19,656*	*408,302*	*6,714,098,500*	*13,292*	*261,301*	*4,145,658,000*	*20,262*	*296,921.25*	*4,926,632,500.00*

Over the last years, mango producers have expanded their operations and replanted their farms with mango varieties that are in demand. Quality planting material and mango saplings are provided by a growing number of certified nurseries. It is expected that the supply and availability of fresh produce will grow exponentially in the coming years as large numbers of recently planted trees will start producing. Increases in production will most probably also lead to increases in post-harvest losses if no measures are in place.

It is estimated that approximately 57 percent of mangoes produced in Kenya is consumed domestically as fresh fruit. 5 percent of the mangoes produced in Kenya is processed for the domestic and regional market and 2 percent of the mangoes is exported as fresh product. The remaining 36 percent of mangos is assumed to be lost before it reaches the consumer (calculations based on data collected during this study and data from Owuor, 2020; World Bank, 2019, and FSD, 2015). In 2018 the earnings of the mango sector totalled 11 Billion KSH; the export market only contributed 1.6 Billion KSH of this total amount (Owuor, 2020).

[7] Kenya Determined to Revitalize Fruits Banned for Export | Science Africa

[8] Extension in hectares, production in metric Tons, Value in KSH

3.1.1.1 Export market

The international demand for Mangoes is growing and expected to grow in the future (see table 4). Kenya voluntarily restricted the export of mangoes to the EU in 2014 to avoid possible sanctions for high incidence of fruit flies. By the end of 2021, this self-imposed ban will be lifted. This opens up interesting new market opportunities for the sector to access a growing and high value market. Currently the main export markets for Kenyan mangoes are in the Middle East (Owuor, 2020).

Growing international and regional demand and the high returns makes mango exporting a profitable business. Kenya's production peak of mango runs from November to January. During that period mango production in other countries is low, providing Kenya with a competitive advantage in the global mango market (Imani, 2019)

The mango sector is experiencing a lot of attention from the Kenyan Government and international development organizations. Amongst their multiple efforts, massive coordinated efforts are being put in place to ensure a fruit fly free zone in the mayor mango producing areas enhancing the opportunities to engage with growing demand of the EU market.

Table 5 *International demand for mangos in metric tons - derived from FAO statistics 2020*

	2007-09	2017-2019	2029
Mango, mangosteen, and guava	5.29819454	7.113604714	8.544637355

The export market tends to be a formal market, that is structured and organized to ensure strict adherence to quality standards, rigorous phytosanitary requirements and other export regulations and norms (Owuor, 2020; World Bank, 2020; Wango *et al.*, 2020). Exporters invest in traceability, and post-harvest management practices and are geared towards maintaining produce quality and complying with regulations and market demands. Exporters invest in temperature controlled storage, transport and aggregation, packaging and distribution infrastructure. As a result post-harvest losses in the export sector are generally very low.

Exporters mostly source their mangos through marketing agents and small-scale outgrower farmers or producer organizations. Business relations are mostly established through formal contractual arrangements. The supply of mango's destined for the export market originates predominantly from medium to large scale commercial mango farms and, from commercially-oriented producer organizations (FSD, 2015). The production investments, administrative requirements and operational records required to warrant access to the export market can be more easily arranged by commercial operations rather than individual small-scale farms.

3.1.1.2 Domestic and regional market

Currently, the domestic market for mango is significantly larger than the export market both in volumes and in value. Within the mango sector, the domestic market - especially urban consumers - is the largest contributor to the economy both in terms of national revenue earnings income generation for smallholder producers (Owuor, 2020). Domestic demand for Mango has grown exponentially over the last years (FSD, 2015; World Bank, 2020). The domestic market is largely informal with a range of stakeholders engaged in specific segments of the supply system. The supply of the domestic market comes primarily from small-scale and medium-scale farms. There is a general lack of market information, a lack of transparency and lack of formal contracts between farmers and buyers in this food supply system.

The domestic market caters primarily for fresh produce although there is a growing trend in the processing segment with some big companies processing pulp and producing mango juice and an increasing number of small-scale processing enterprises engaged in pulping, dehydrating and other forms of post-harvest value addition (Owuor, 2020).

Most mangoes are sold in informal, wet markets. A study by FSD highlights that in 2015 only 2 percent of the domestic fresh mangoes were retailed in supermarkets catering for middle and upper income consumers (FSD, 2015).

Kenyan mangos are also popular in the regional markets; predominantly in Tanzania and Uganda. According to studies, Tanzania imports approximately 5000 metric tons of mango a year (Owuor, 2020).

3.1.2 Kenya's mango supply system and the environment

Kenya's diversified agro-ecological landscape has the potential to produce mango's throughout the largest part of the year. Due to its diverse climatological conditions it is possible to source from different counties in different seasons although peak production cycles cover seven months of the year (Owuor, 2020).

Changes in temperature and rainfall distribution have strong effects on the mango sector; creating adverse climatological conditions for the production of quality mango (droughts, excessive heat, etc.) and increasing the distribution of detrimental pest and diseases. Climatological variability in Kenya is currently already creating new challenges for small-scale mango farmers, commercial mango farmers and agribusinesses alike.

Contrary to large-scale mango orchards that generate larger yields, small-scale mango farming practices tend to have reduced impacts on the environment. Small-scale mango farming practices tend to use limited land and water resources. Managing mango orchards through Good Agricultural Practices and Integrated Pest Management has potential to significantly reduce the environmental impact of agrochemicals utilized in mango production.

On farm mango losses are often left on the land or used to feed domestic animals. Waste from harvested mangoes that are discarded and not disposed of properly, can generate environmental hazard.

3.1.3 Overview of the mango supply system

3.1.3.1 Agricultural production

The largest volumes of mangos are sourced from smallholders. These production systems typically fall under the rural, traditional, informal and expanding food system typology described in chapter 2. On average small-scale mango farmers manage a range from 20 to 300 trees (Owuor, 2020). Small-scale mango production integrates easily with the production of staple crops (maize, beans, others) and allows smallholder families to diversify their production and income sources thus strengthening resilience in smallholder food systems. In addition it has the potential to provide a nutritious source of fresh fruit for smallholder families and domestic consumers at affordable prices. Owuor (2020) estimates that revenues from mango production contribute to approximately 40 percent of household income in some counties (for example Machakos and Makueni).

A growing number of nurseries and agricultural input providers supply farmers with high quality planting materials and agricultural inputs to improve production and productivity (Owuor, 2020; World Bank, 2020). County governments and national regulatory institutions have strongly supported these activities.

During the production stage, mango is particularly vulnerable to pest and diseases. Integrated pest management, pruning, and post-harvest management can improve production, productivity and product quality but required additional investments in terms of labor and inputs. Under the current conditions, small scale producers are generally not inclined to invest in infrastructure or management practices that mitigate and reduce losses due to the informal nature of the supply system, the relatively small quantities of produce that individual farmers handle and the very small returns that are generated (Owuor, 2020; World Bank, 2019; Imani, 2019; Wangu *et al.*, 2020). Mangoes are perishable and delicate fruits. To mitigate the risk of mangoes spoiling, farmers are inclined to sell swiftly after harvest. Most small scale farmers do not have on-farm storage facilities and rely on marketing agents to connect to the market (Owuor, 2020).

Although there are examples of commercially-oriented small-scale farmers who have organized themselves in producer organizations investing in market linkages, the large majority of farmers are not horizontally or vertically integrated within the supply chain.

3.1.3.2 Food storage, transport and trade

In most cases the first post-harvest transactions in the mango supply system are between smallholder farmers and mango marketing agents also referred to as middlemen, vendors or brokers (Owuor, 2020). The role and power that marketing agents hold within the entire supply chain is of significant importance. Marketing agents often offer harvesting and transport services deducting these costs from the total value of mangos purchased from a farmer. In that position they are able to negotiate prices of mangos as most farmers are not willing to invest in labor to harvest the small volumes on their land and transport them to the nearest selling point. In the peak of the productive season the market is saturated and prices fall drastically.

Marketing agents form a key linkage between producers and the market. They often operate in multiple counties and supply both rural wholesale markets, urban wholesale and retail markets, regional wholesale markets and processors. There are limited cases of marketing agents working together with exporters to supply high quality mangos sourced from smallholder farmer organizations. Even though marketing agents have relatively good access to real time market information, during peak production seasons they run the risk of arriving at a wholesale market to find it completely saturated.

Freshly harvested mangos are often packed in bulk, transported in non-refrigerated vehicles, being subjected to bruising and stored in non-cooled environments, indicating that both non-refrigerating and bruising are major problems (Owuor, 2020; World Bank, 2019; FDC, 2015 and Interviews this study). The magnitude of these losses constitute strong economic risks for the marketing agents. To avert these risks, the anticipated economic loss is calculated in the prices they offer farmers at the farmgate. Therefore the current levels of post-harvest loss principally affect mango farmers. Formal agreements between vendors and farmers are not common. In the majority of cases, farmers and marketing agents make informal offtake agreements and agree upon a predetermined price.

Marketing agents have taken up a particular niche in this sector as a result of the lack of storage and aggregation facilities for mango at a local and county level. The facilities that exist in some counties (for example in Machakos and Embu – Masii and Karurumo aggregation centers respectively) have a carrying capacity that falls below the production potential of these counties.

The sector producing for the domestic market is largely informal which means minimal market organization, insufficient market information, generally no contracts. Post-harvest losses are high as a result. Formalization, certification and strengthening post-harvest management activities of the marketing agents would have a positive effect on the reduction of losses, improving the availability and affordability of mangos. A large majority of small-scale mango farmers does not have access to the financial means to make these investments (Wango *et al.*, 2020).

3.1.3.3 Food processing and transformation

Currently only five percent of the mangoes produced in Kenya is processed. Mango processors do not source mangos from farmers directly but rather from marketing agents. Globally, regionally and locally there is a growing demand for processed mango products warranting potential for sector development[9]. Mangos that are utilized for processing also have certain quality standards; damaged mangoes cannot be processed. Mangoes that have cosmetic deviances can be processed. It is assumed that a small proportion of the mangoes that are rejected at wholesale will end up at a processing facilities (Interviews in this study).

There is a growing domestic and international market for processed manufactured mango products ranging from, pulp, ready-made juices, dehydrated mango, dehydrated mango powder and a range of other consumer and cosmetic products. Currently, processing of mangoes into pulp is the primary activity with manufacturing into ready-made consumer products being a smaller activity in Kenya.

Small-scale (cottage industry) process small volumes of mangoes locally. Medium to large-scale mango processing takes place in and around Nairobi and at fruit processing plants that are located in the vicinity of mango production clusters. Mango processing is predominantly undertaken by farmer groups or commercial mango processors.

> The Kalamba Fruit Processing plant that operates in Makueni has generated a positive impact in the county. By providing a market outlet where farmers get a good price for lower grade mangoes, the fruit processing plant has altered the market dynamics in the county (Owuor, 2020 and stakeholder interviews from this assessment). Currently, the plant cannot operate at full capacity because it does not have access to a consistent supply of quality mangoes. The lack of aggregation and temperature-controlled storage facilities in the vicinity of the processing plant limits their capacity to collect fresh produce in the peak harvest season, and storing it for processing when the availability of mangoes is reduced.

Entrepreneurial activities and investments to process mango are increasing. Although this activity is not a widespread industrial-scale activity at the moment; it is coined as a lucrative economic activity that can be driven by SME's if the linkage with the market is established. A number of studies on viability of mango dehydration plants have calculated positive returns on investment from small and larger scale processing activities (Mujuka *et al.*, 2019).

3.1.3.4 Wholesale and Retail

Mango wholesalers operate in major wet markets in urban centres and cities. Wholesalers source vast amounts of mangoes from different marketing agents and different counties. There are a limited number of cases where the wholesaler sources directly from the farmer. Due to the informal nature of the sector and lack of traceability records it is difficult to distinguish the origin and source of the mangoes sold by wholesalers

Generally speaking wholesalers do not have access to adequate cooling and storage facilities for fresh produce. Although data of food losses in this stage of the food supply chain is largely lacking, it is assumed that losses are considerable.

Retailers, supermarkets, hotels and restaurants tend to source their mangoes through marketing agents and producer organization that can provide high quality mangoes. The volumes of mangoes that are currently sold to supermarkets, hotels and restaurants represent a very small share of the end market. Market trends indicate that a growing middle class in and around urban centers is increasingly willing to pay premium prices for safe and high quality mangoes purchased in supermarkets.

[9] https://sdginvestorplatform.undp.org/market-intelligence/fruit-processing

3.1.4 Contribution of the mango supply system towards food system outcomes

3.1.4.1 Income and employment

There are large numbers of small-scale, medium scale and organized farmers in Meru, Embu and Machakos counties whose livelihoods are intimately linked to the mango sector. Mango production is often considered an additional and diversified source of income that builds economic resilience in rural landscapes by allowing small scale mango production along with staple crops. Due to the informality of the sector and the relatively low rates of return for small-scale farmers, mango production is generally considered a complementary economic activity rather than a primary one.

A study that looked at mango farmers' small-scale value addition activities in Machakos County highlights that a large degree of farmers are involved in value-addition activities of some sort. Farm size and membership of a farmers organization were key determining factors for engaging in value addition (Musyoka *et al.*, 2020).

During peak seasons the mango sector creates sources of employment for laborers, harvesters, transporters, marketing agents and small scale processors. Production is often driven by older farmers whilst young men and women are predominantly involved in off-farm activities operating as marketing agents, processors, handlers, transporters and service providers (Owuor, 2020).

Inclusive sector development and post-harvest loss reduction has the potential to improve farmers' livelihoods whilst targeting pro-poor interventions that include rural women and youth. Increased horizontal integration of producers into producer organizations and vertical integration within the supply chain and subsequent market integration are complementary requirements that will drive inclusive sector transformation. support for value addition can increase the number of off-farm employment opportunities.

3.1.4.2 Nutrition and food security

The mango sector has the potential to structurally contribute to domestic nutrition security through the supply of a popular food product. By providing a tasty source of nutritious fresh fruits at accessible prices, mango makes a considerable contribution to the intake of daily required essential vitamins and minerals in addition to the calories and, to a lesser degree the proteins (ICRAF, 2003)[10].

Mango is relatively rich in Vitamin A (one fruit contains about 8 percent of the daily need). Vitamin A is one of the micronutrients that is mostly lacking in diets in low-income countries. The World Health Organization (WHO) considers Vitamin A deficiency as a major threat to the health of children and pregnant women in low-income countries.

The WHO recommends eating at least 400g of fruits and vegetables per day. The current availability of vegetable and fruits in Kenya is estimated at 300g per capita. Increased access, affordability and availability of mango in the domestic market can contribute to reduced consumer prices and increased consumption.

That having said, there are accounts whereby small-scale mango farmers, through increased sales in the mango export market, have improved their income but have not improved their food and nutrition security status (Wangu *et al.*, 2020). Therefore one cannot assume that improvements in income directly translate into improved nutrition and healthy diets.

[10] http://apps.worldagroforestry.org/Units/Library/Books/PDFs/97_Mango_growing_in_kenya.pdf

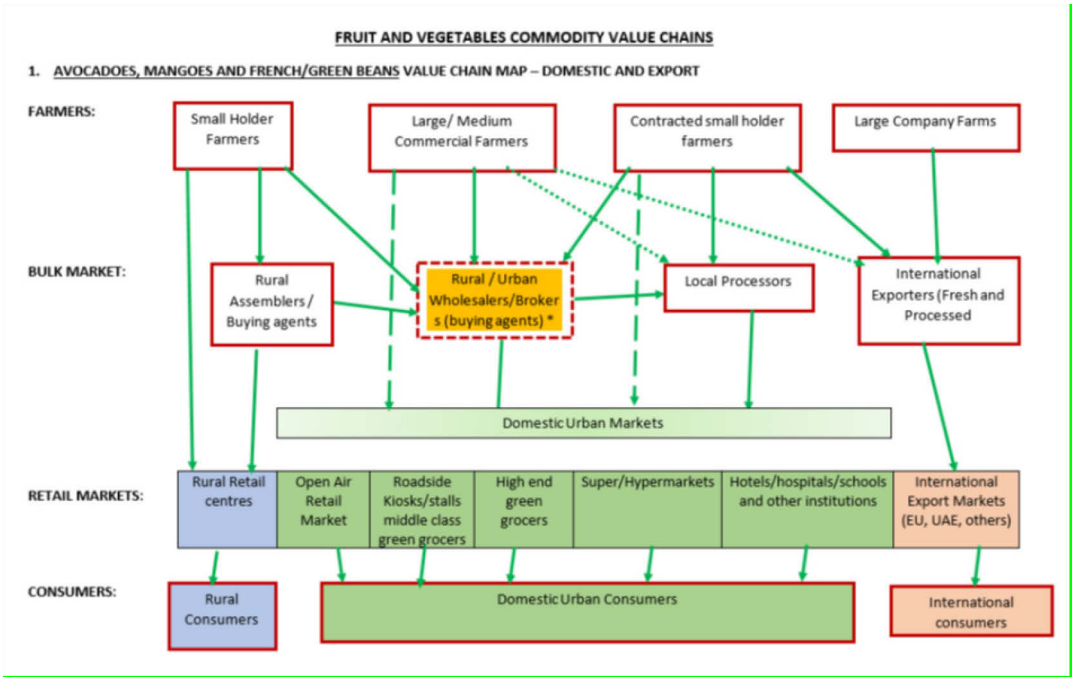

Figure 2 *Overview of the mango and avocado supply chain (Source: Research Solutions Africa 2018)*

3.2 Mango post-harvest losses

Integrated efforts to tackle losses in the mango sector must pay attention to the production stage as it is directly and indirectly related to post-harvest losses. On-farm production related interventions have significant potential to reduce losses. This analysis however explicitly focusses on interventions and leverage points targeting losses after the product has been harvested. This choice was made because there are already a vast amount of investments, research and field based projects that target the reduction of losses during the production process.

3.2.1 Critical loss points in the mango supply system

The following section describes the critical-loss-points (stages in the mango supply system where losses are high) and the main causes of these post-harvest losses.

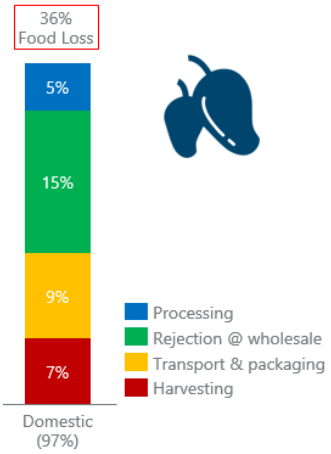

Figure 3 *Post-harvest loss profile for mango*

Post-harvest losses are significantly higher in the domestic supply chain when compared to the export supply chain. Management measures to minimize losses are more common in the export supply chain (Owuor, 2020 and findings from this assessment). Considering that the domestic supply chain has the highest loss reduction potential, consumes largest volumes of mangoes and has the strongest direct contribution to SDGs and food system outcomes the analysis focuses on the domestic supply chain. Many of the mentioned leverage points for loss reduction are however also applicable to operations of exporters or farmer organizations that export mangoes.

Post-harvest losses occur on-farm, during transport, during storage at wholesale markets and at retailers premises. Major causes are – next to oversupply during peak season – improper handling, pests and diseases. In addition there is a general lack of temperature-controlled storage during transport, at wholesale and retail points (World Bank, 2020 and Owuor, 2020, Advance consulting, 2019).

As is illustrated in figure 3, mango losses occur at different stages of the mango supply system. It is estimated that in the domestic market, on average, 36 percent of the mangoes that are produced are lost before they are consumed.

The first critical loss point for mango relates to "first-mile" activities such as harvest, transport, packaging and storage. These activities have significant influence on product quality and shelf-life. Of the total losses, almost half are incurred during these first-mile supply chain stages.

The second critical loss point is linked to the moment where mangoes arrive at the wholesale market where damaged and poor quality mangoes are rejected. These losses are attributed to inadequate handling practices in previous stages (harvesting, packing, transportation and storage). These losses represent 15 percent of the total production and more than one third of the losses in the mango sector.

The five percent loss that is generated at the processing stage is attributed to a lack of adequate aggregation, storage and temperature-management at processing facilities.

3.2.2 Economic impact of post-harvest losses

In order to understand the economic impact of post-harvest losses, this analysis looked at the price of mangoes at a particular transaction stage and correlated that value to the percentage of loss that was identified for that stage in the food loss profile (see figure 3). By matching these variables to the respective transaction between a "product owner" and a "buyer" the analysis uncovered how losses along the supply system affected different stakeholders.

This analysis starts from the current price of mango at different transaction stages. We assume that the current profit margins throughout the different transactions internalize the economic risk of losses by offering low farm gate prices in comparison to the wholesale and retail prices (FSD, 2015; Owuor, 2020). Hence farmers obtain a very low farmgate price while the price of mango at wholesale destination is threefold.

Based on a farm-gate price of KSH 21 per kg (Owuor, 2020), in the transaction between farmer and marketing agent the post-harvest losses hypothetically reduce the farmers' income by KSH 1.5 per kg sold due to 7 percent harvesting losses.

The 9 percent losses during "transport and packaging" represent an economic loss for marketing agents of KSH 3 per kg traded (based on typical agents' selling price to wholesalers at KSH 35 per kg).

The 15 percent rejection losses that have been identified at wholesale are a significant part of the post-harvest loss. They are partially accredited to inadequate handling and lack of temperate control in transport and storage but are also indirectly related to inadequate quality management in the 'first mile' of the post-harvest chain. Based on wholesale price of KSH 65 per kg, the economic loss for the marketing agent at this stage of the supply system is estimated at KSH 10 per kg mango produced.

Table 6 *Economic loss at critical loss points*

Critical loss point	Economic value lost
Farmgate	1.5 KSH per Kg sold
Transport and packing	3.0 KSH per Kg sold
Rejection at wholesale	10 KSH per Kg sold

By looking at the total economic value of the mangoes that would not be lost if loss-reducing measures were in place one can approximate budget space for investment. For example, a post-harvest investment that would warrant a reduction of 5 percent of total losses incurred in the first mile by a mango producer (and assuming that the current prices are not affected) would increase farmers' annual income by about KSH 9,500 (assuming 117 trees per farmer, each bearing 232 – 78kg - fruits on average). An increase of approximately 25-30 percent compared to their current annual revenues.

3.2.3 Leverage points for post-harvest loss reduction in mango

Leverage points for post-harvest loss reduction have been identified based on the critical loss points and the economic impact analysis. The identified loss-reducing leverage points correspond to particular stages and factors in the mango supply system where modifications can lead to reduced post-harvest losses in the entire mango supply system (Posthumus *et al.*, 2021).

The leverage points describe a particular facet of the supply system and a series of sector level approaches rather than single interventions. Leverage points do not imply specific activities that specific stakeholders must engage in but allude to stronger horizontal and vertical integration and supply chain coordination.

3.2.3.1 Product handling and temperature management

This leverage point targets the post-harvest losses incurred during handling, storage, transport and marketing.

The quality and shelf life of mangoes is strongly affected by first mile product handling and temperature management. For the case of mango – with a typical shelf life of 2-3 weeks under optimal cold storage conditions at 10 to 13 °C – respiration/deterioration is increased by about 5-fold at 25°C (derived from Kader, 1997 and Gross *et al.*, 2016). This means that keeping the product at ambient (generally high) temperature at the beginning of the post-harvest chain will significantly harm the quality and shelf life on the market. Cooling throughout the supply chain is most effective especially if it includes post-harvest precooling and an uninterrupted cold chain. It is estimated that lowering the product temperature from 20-30 to 10-13°C for 2 days in the first stages of the post-harvest chain would increase the shelf life on the market by over 36 hours if the product is kept at ambient temperature (or up to 8 days extra when refrigerated). Refrigeration during transport would furthermore facilitate moving the produce to the (relatively remote) urban market without violating shelf life. By combining temperature management with packaging solutions also mechanical damage can be minimized. Temperature-managed storage facilities can create a storage buffer for processing and value addition. It can reduce losses and extend the seasonal sales period at wholesale markets (up to 2 weeks).

Temperature management during the "first mile" is critical for quality assurance throughout the value chain. For maximum effectiveness, temperature management should be initiated as quickly as possible after harvest. This implies that small-scale systems near the farm are more effective than a facility near the market. First mile temperature management can be simple, lo- tech and low-costs mechanisms and practices that reduce exposure to climatological elements and reduce core temperature. These include amongst others shading and use of small-scale evaporative cooling facilities.

3.2.3.2 Agro-processing and transformation

Agroprocessing is an economic activity that has the potential to increase employment opportunities and add value to fresh mangoes locally. Although there is a growing market for processed mango products domestically, regionally and internationally only a very small percentage of mangoes is currently processed at industrial scale. Recent studies in Machakos and Embu highlight how considerable percentages of farmers engage in informal small-scale mango processing and value addition activities (Musyoka *et al.,* 2020). Industrial processors operate in certain counties but are often restricted in operating at full capacity for being unable to obtain stable supplies of quality mangoes. Processors require mangoes of good quality. Cosmetic requirements are not stringent but quality requirements are restrictive.

Ready-made food products are often required to comply with regulations comparable to formal fresh food markets. Considering that the largest volumes of mangoes in Kenya circulate in the informal sector, lack of traceability and product information currently restrict informal processors to enter that market segment. Currently the largest share of mango processing activities focus on pulp production and ready-made juices. Actors are mainly industrial scale processors. In addition there is a growing trend in dehydrating mango which is picked up by farmer organizations and small scale businesses. Mango is an incredibly versatile product that can be transformed into different end products ranging from food to cosmetic products. Many of these markets are growing and offer great market entry opportunities[11]. Certification and traceability of mango producers and processing operations will enhance the possibilities of processed mango products to establish linkages and supply formal markets, domestically, regionally and internationally.

Transforming mangoes into high quality animal feed is an emerging opportunity for mangoes that are not suitable for human consumption. Mangoes are very effective for feeding black soldier fly larva which can be utilized and transformed into protein rich animal feed products[12].

More details on opportunities to transform lower quality mangos into high value products are described in chapter 5.4.

Mango processing and transformation has the potential to generate off-farm employment opportunities for young men and women and agri-entrepreneurs.

3.2.3.3 Digital innovations for improving market linkage and agri-finance

Small-scale farmers are often limited in their capacity to access market opportunities as they have poor access to market information, poor access to finance for capital investments, and limited capacity to keep records of their farm operations. The informal mango sector is plagued by a lack of formal contracts, lack of price information and transparency and lack of traceability of products and production practices. A diverse array of digital solutions is emerging in support of smallholder farmers and the value chain stakeholders they interact with (GSMA, 2020). Many of these digital innovations warrant effective application in Kenya's domestic mango supply system to generate innovative pathways that allow smallholder farmers access to agri-finance products.

Many small-scale mango farmers operate informal supply systems and lack formal contracts, fixed buyers, fixed prices, access to transport and storage infrastructure for their perishable fresh harvested mangoes. Smallholders are often left with no other choice as to work with marketing agents to access markets and get some revenues from their mango harvest. Distributed ledger technologies and block chain applications have the potential to make the informal supply chain more transparent and provide important price and market information to small-scale farmers and product information to potential consumers. Increasing demands for fair and transparent procurement mechanisms and farm to fork traceability are generating promising innovations in niche markets where digital procurement is linked with traceability, digital records and payments and access to markets (GSMA, 2020).

[11] SDG investor platform https://sdginvestorplatform.undp.org/market-intelligence/fruit-processing

[12] Circular business in Kenya: from waste to cattle feed | News item | Government.nl

3.2.4 Technology options for post-harvest temperature control

Different technology options for post-harvest temperature control are available, corresponding to different scales and levels of application:

- Low-costs, farm-level evaporative (zero-energy) cooling technologies offer cost-effective post-harvest management interventions that have proven to be effective and provide a good return on investment at farm, co-operative or community level[13]. Evaporative cooling is a relatively inexpensive solution for slightly lowering room temperature (typically 3 to 5 degrees below ambient temperature[14]). This method is effective because of the significant reduction of respiration degradation and reduction of moisture loss from the product. Evaporative cooling is an effective solution for on-farm precooling but it cannot replace temperature controlled cooling solutions.
- Medium-scale (container-sized, mobile, 20 ft), medium-tech solutions that integrate post-harvest handling and market linkage platforms offer good opportunities for mobile, first-mile, cold storage and aggregation. Rather than farmers investing in these cooling solutions by themselves the container is offered as a service package whereby a group of individual producers pay for its use, without having to finance the initial capital investments. This particular type of technology option and scale would be appropriate at a village level allowing aggregation of fresh mangoes from multiple farmers. This type of cooling solutions can operate through different business models: by farmer organizations managing the facility or by investors and service providers offering the service together with digitized procurement tools and market linkages[15]. Aside from the technical possibilities of temperature management, the operational structures and business models of these scale of temperature controlled storage and aggregation is fundamental for their functioning. The cooling facilities can be solar powered or powered by the electrical grid and tend to be mobile to facilitate modular mobility throughout the productive season.
- Medium-to-large-scale, high-tech cold storage and aggregation centres in logistical hubs such as Nairobi or Murang'a, offer opportunities for large-scale farmers, farmers organizations and exporters to aggregate, store and handle larger volumes of mango. Investments range from EUR 80,000 to 5 million EUR with operational costs depending on energy usage (solar or electricity) and labour costs. Considering the initial investment costs, large volumes of fresh product are required to operate at this scale successfully. Ideally this scale of cooling facilities would operate at a port of export, large wholesale market or next to a large-scale processing facility.

Effective organization of the mango subsector would ideally see a complementary mix of the above storage solutions (including refrigerated transport) to ensure a minimum post-harvest loss. All three technologies are proven widely. Economic viability of the options will depend on the local context. In the above analysis the focus was put on the domestic market, and considering the mango post-harvest losses profile (figure 3). These conditions warrant for medium scale, mid-tech solutions. A cost-benefit assessment of this option is worked out in chapter 5 of this report.

3.3 An overview of the avocado sector

3.3.1 Markets and Policies

The avocado sector is one of the key areas for horticulture sector development in Kenya and is prioritized in a series of development policies and county level investments. Kenya is the world's seventh-largest producer of avocados and ranks eleventh on the list of largest exporters (World Bank, 2019; Imani, 2019). Since 2017 Kenya is Africa's leading avocado exporter (Avocado Society of Kenya, 2020). Kenyan produced avocados are in demand locally, regionally and internationally.

Kenya's favourable agro-ecological diversity and good growing conditions combined with increased domestic and international demand for mango has driven the expansion of the sector over the last decade. Government support through targeted investments and enabling policies have been crucial in

[13] (Manyozo *et al.*, 2020)

[14] Ibid

[15] For examples in Kenya see: https://enviu.org/work/sokofresh/ and https://www.inspirafarms.com/

developing and integrating the sector both horizontally and vertically resulting in improved quality of production, improved productivity and creating an enabling environment for exporters.

In 2018, avocado was being produced on approximately 15,000 hectares of land, producing 318,000 metric tons (Owuor, 2020; HCD, 2019). The vast majority (approximately 70 percent) is consumed domestically. Total acreage of avocado has been increasing over the years; in 2020 the area under avocado surpassed 20,000 ha (Kenyan Avocado Society, 2020). Production growth is attributed predominantly to an increase in acreage and only moderately due to increase in productivity (Imani, 2019).

Commercial, marketable production (Hass variety) is estimated at about 60,000 to 90,000 metric tons (produced on 7,500 hectares). Export accounted for 63,300 metric tons in 2019 and is estimated to be 80,000 metric tons in 2020. As figure 4 illustrates, 60 percent of avocado exports are transported to Europe (the Netherlands, France, Spain)[16]. Other growing export markets include the Middle East, China and India (World Bank, 2019).

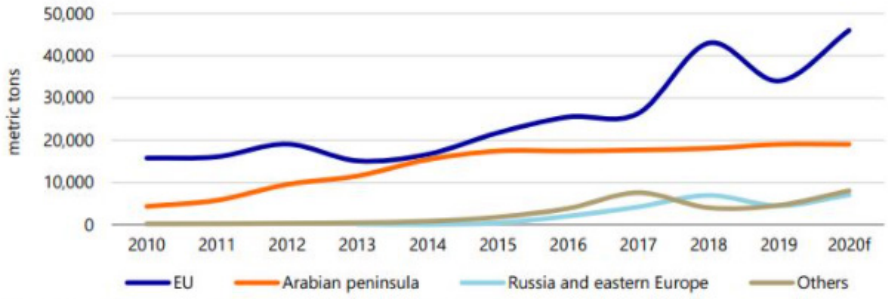

Figure 4 *Avocado exports from Kenya by destination 2010-2020 (Source Un-Combtrade, FruiTrop/CIRAD, Eurostat, Rabobank, 2020)*

Avocado is coined as one of the key horticultural products in Kenya that warrants further investments aimed at integrated sector development. In order to improve market connection and reduce food losses the sector requires bundled and customized investments at different scales including the production phase and the post-harvest supply chain stage (Vershoor *et al.,* 2020*).*

The avocado sector features prominently in a series on national policies and county level investment strategies such as The Big Four Agenda, the Agricultural Development and Sector Transformation Strategy and the Kenya's export agenda. The NARIGP project that is being implemented at county level has coined the avocado sector as one of its key priority sectors. Significant investments not only for production and productivity improvements but also for post-harvest management and infrastructure are contemplated together with horizontal aggregation and strengthening of small-scale avocado farmers' organizations[17].

Among others, these investments have been successful in the establishment and regulation of numerous certified nursery operators who supply high quality planting material. It is assumed that in the years to come, recently planted avocado saplings will enter their productive cycles exponentially increasing the volumes of avocado. Without the adequate investments and strategies, it is possible that the increases in production may result in an increase in the total volumes of avocado losses.

[16] UN-Comtrade, FruiTrop/CIRAD, Eurostat, Rabobank 2020; ITC Trade Map. Available through: https://research.rabobank.com/far/en/sectors/fresh-produce/kenya-avocado-sector-growing-fast-but-still-growing-up.html

[17] https://projects.worldbank.org/en/projects-operations/project-detail/P153349

Avocado is a potential crop in Meru County providing significantly to rural household incomes. The county invests heavily in developing the sector. It started a seedling nursery at the county Agricultural Training Center and promotes adoption of marketable varieties by selling the seedlings at a subsidized price of KSH 120 per piece. There are several exporters buying avocados in Meru. To fully make use of the opportunities farmers need to be organized into producer organizations for easier access to better markets and training services for improved production and more effective market linkages.

Avocado growers, exporters, and other value-chain players in Kenya have recently founded the Avocado Society of Kenya. The society aims to promote cooperation among stakeholders in the value chain and gain access to new export markets.[18]

3.3.1.1 Export market

Between 10 to 30 percent to Kenya's avocado production is either exported as fresh product or processed locally and exported as crude avocado oil (Amare *et al.*, 2019). The export market for avocados is growing exponentially due to an ever increasing demand. According to the Horticultural Crops Directorate Kenya's avocado exports in 2020 hit 72,000 tons, a considerable increase from the 59,000 tons exported in 2019[19]. European demand for avocado is growing and is expected to continue to absorb more avocados as the consumption of avocados has grown by 8 percent between 2017 and 2019 (CBI, 2021).

The value of Kenya's avocado exports jumped 93 per cent to 4.26 billion KSH between January and March 2021 compared to a similar period last year, according to the Horticulture Directorate[20]. Furthermore, according to ColdSolutions, Kenya is in an excellent position to fill the supply gap in the Chinese market[21]. The Chinese market for pulped avocado is 100 million MT, of which now 70 percent is fulfilled. The remaining capacity is as large as the whole of what is exported to Europe. At present, Kenya exports 70,000 MT/year to China.

The export market is quite formal and structured to ensure strict adherence to quality standards, sanitary and phytosanitary requirements and export regulations (Amare *et al.*, 2019; World Bank, 2020). Traceability, product regulations and GAP certificates are important requirements to enter the export market. The vast majority of Kenyan produced avocados do not meet the stringent requirements to access the high-value export market. Significant on farm investments are required to change that. Small-scale farmers are not always in a position to make these investments nor do they have access to agri-finance products that cover these types of costs. As a consequence the highly profitable export market is inaccessible for the largest majority of small-scale avocado farmers (Amare *et al.*, 2019; Imani, 2019; Rampa & Dekeyser, 2020).

A limited number of large-scale export companies dominate the avocado export market, for example, Vegpro, Sunripe, Keith, Kakuzi, East African Growers, Kenya Horticultural Exporters, Mutanda and Ideal (Amare *et al.*, 2019). Some of the large avocado exporting companies have long standing relationships and formal contracts with small-scale avocado producers or producer organizations. Some companies support the farmer groups with training, advisory services, certification and other requirements to access the export market (Imani, 2019). Others tend to source from medium or large scale growers or their own plantations. Yet others source directly through marketing agents who aggregate volumes of high quality avocados before handing them over to the exporters (Amare *et al.*, 2019). In addition to these large-scale exporting companies, there are considerable amounts of small-scale exporters that ship small volumes of avocado (Imani, 2019 and interviews from this study). Small-scale exporters tend to have a diverse portfolio of different export commodities.

[18] About us (kenyaavocados.co.ke)

[19] https://www.freshplaza.com/article/9311777/kenyan-avocado-exports-at-72-000-tons-in-2020/

[20] Kenya seeks to tap growing avocado demand in Egypt - Business Daily (businessdailyafrica.com)

[21] Interviews this study

Kenyan avocados used to be exported by air freight. The associated transportation costs made them less competitive in the market. The introduction of reefers (refrigerated shipping containers that can cool avocados during sea transport) has changed the market logistics and created new possibilities to access distant and lucrative markets such as the European market through sea freight (Imani, 2019).

The Netherlands absorbs over half of Europe's avocado imports and plays a key role as distributor and trade hub for avocado throughout Europe (CBI, 2021).

Due to the high-value of the merchandise, avocado exporters invest in post-harvest management and loss reduction practices and often work by integrating vertically with producer organizations, training them on orchard management, good agricultural practices, quality assurance and post-harvest management. According to the assessment from this study, post-harvest avocado losses in the export supply system constitute approximately 15 percent of the total export volume.

3.3.1.2 Domestic market

The domestic market consumes more than two-thirds of total national production of avocados and is largely informal. Avocados are a popular product in Kenyan diets and are sold in wholesale markets and smaller retail shops. Supermarkets in commercial urban hubs sell avocados that are frequently of better quality than those found in small rural retail shops.

There is a general absence of market information and lack of transparency in the domestic avocado market. Only a small number of avocado farmers are formally organized into producer organizations and have contractual arrangements with marketing agents and buyers (Imani, 2019; Amare *et al.*, 2019; Rampa & Dekeyser., 2020).

Three industrial-scale avocado oil processing companies have established in Kenya fairly recently creating a growing demand for 2nd grade avocados. This has created an additional market that would previously be discarded as these lower grade avocados are not suitable for export or the domestic market but are suitable for processing into avocado oil. As there is no market for avocado oil in Kenya, the crude oil is exported to be further refined and processed abroad[22].

3.3.2 Environmental drivers affecting the avocado supply system

Avocado production in Kenya has two seasons, the first is a season with large production volumes running from April to July and the second a season with a smaller harvest from September to October. The season from April to July provides Kenya with a competitive export niche as supply of other global exporters (predominantly from Latin America) is limited in this period (Imani, 2019).

Although avocado is reasonably resilient to low rainfall conditions, fruit size, shape and quality is affected by deficient access to water. Small-scale avocado farmers generally do not have access to irrigation and are therefore vulnerable to variability in rainfall. Only a select number of large scale commercial avocado farms have access to irrigation and can warrant uniform production quality. Climate variability accompanied by outbreaks of pest and disease affects quality of avocado reducing their the export potential.

3.3.3 Overview of the avocado supply system

3.3.3.1 Agricultural Production

Currently, more than 70 percent of avocado is produced by small-scale farmers whose production systems typically fall under the rural, traditional, informal and expanding food system typology described in chapter 2. Small-scale farmers harvest from 5-20 avocado trees dispersed throughout their land holdings. 20 percent of avocado production originates from medium-sized producers who manage over 100 trees. 10 percent of the total avocado production volumes is produced on large commercial plantations that produce on 10 hectares or more (Imani, 2019 based on ITC, 2015).

[22] A detailed reference of one of these avocado oil companies is provided in chapter 5

The majority of small-scale avocado farmers have avocado trees intercropped with tea, coffee, banana, maize and other staples (Owuor, 2020b) The income they generate from avocado production supplements their primary income sources obtained from the production of staple and cash crops. In general most small-scale farmers do not invest heavily in orchard management, production, post-harvest, management, etc.

3.3.3.2 Food storage, transport and trade

The vast majority of small-scale farmers (approximately 99 percent) engage with marketing agents who cover the costs of harvesting and transportation of the produce (Owuor, 2020). Marketing agents supply to the wholesale markets, small retail outlets, supermarkets and hotels and at times also to exporters. Very few avocado farmers sell directly to exporters or processors.

Although farmers obtain a low farmgate price when selling to brokers, marketing agents are the preferential channel for most small-scale farmers to connect to the market. Marketing agents tend to pay for the purchased avocados on the spot, and at times even in advance. In addition, they cover all the costs of harvesting, grading and transportation (Imani, 2019; Amare *et al.*, 2019).

Marketing agents send out harvesting crews who generally tend to shake trees and collect the fallen avocados packing them in 50 kg, 100kg or 130kg sacks (Owuor, 2020b). Avocados are transported to local markets on motorcycles, in busses and on the top of lorries. During harvest, transport and storage, the fruit stored in sacks is handled roughly and temperature management is virtually non-inexistent. These factors strongly affect rejection rates and therefore influence post-harvest losses. The marketing agents anticipate these losses as their 'invisible' costs and offer very low farm-gate prices to farmers.

Contrary to the avocados destined for the domestic market, avocados that are sourced for the export market are considered high value products which are harvested, handled, transported and traded with care. Transactions for the export market are handled per unit of avocado, whereby they are packed into cartons of approximately four kilograms (4-6 units of avocado). Adequate investments in post-harvest handling, transport and packaging of avocados for the export market have proven to greatly reduce post-harvest losses (Owuor, 2020).

3.3.3.3 Food processing and transformation

Few avocado processing companies operate in Kenya. Mostly they process avocado into crude oil which is exported to be refined and further processed abroad. One enterprise is currently engaged in refining avocado oil locally to export a higher grade oil ready for consumption. The demand for avocado oil is expected to grow in the coming years.

Since 2017 Kenya has been trying to access the growing Chinese market for avocado. Chinese inspection authorities' voiced their concern regarding the lack of trackability, quality assurance and adherence to strict phytosanitary regulations. As a result the export of fresh avocados was denied but an option was provided to export peeled, cut, packed and frozen avocados[23]. These conditions and the required capital investments are out of scope for the large majority of small-scale avocado farmers. Since 2019 only two export companies have been able to comply with the regulations and requirements to export to China. There are projections that the Chinese market has the potential to absorb 40 percent of avocado production from Kenya (Imani, 2019). The growth in consumer's demand for healthy foods creates an array of possibilities to add value to avocado processing it into consumer products such as baby food, avocado flour, cosmetic products, and many more.

3.3.3.4 Wholesale and retail

Avocado wholesalers operate throughout Kenya in wet markets near urban centers and larger cities. Avocado retailers can be found in rural and urban settings. In most cases both wholesalers and retailers obtain their avocados through marketing agents. Due to the informality of the sector and the lack of traceability it is virtually impossible to distinguish the origin and source of the avocados sold at

[23] https://developmentreimagined.com/2020/10/02/fresh-or-frozen-should-kenya-and-china-renegotiate-their-2019-avocado-deal/

wholesale and retail level. The lack of market information also limits the ability of marketing agents to know where there is demand for fresh avocados. During peak harvest times, where there is a market glut, marketing agents run the risk of arriving in a locality with a truckload of avocados to find out that the market is saturated.

The volumes of fresh avocado that are currently sold through supermarkets, restaurants and hotels is fairly limited. There is a growing trend of middle class urban dwellers who shop at supermarkets and are willing to pay premium prices for safe and high quality avocados.

3.3.4 Contribution of the avocado supply system towards food system outcomes

3.3.4.1 Income and employment

Large numbers of small-scall farmers in Muranga, Kisii and Meru counties rely on the production of avocados to complement their livelihoods. Avocado production is generally complementary to the production of subsistence and staple crops and therefore contributes to income diversification and resilience building. Due to the low rates of return and the informality of the sector small-scale farmers do not specialize in avocado production. An analysis of avocado farming in Meru county reveals that avocado production is dominated by older male farmers. The average income from avocado farming in this county, based on surveyed small-scale farmers, totalled 40,000 KSH per year per household (Owuor, 2020b).

During the peak production season the sector creates employment opportunities for seasonal laborers, harvesters, marketing agents and transporters. Medium to large scale exporters and processing companies create additional off-farm employment opportunities. Medium to large-scale exporters and processing companies tend to employ large numbers of women (80 percent) who are tasked with packing, processing, cleaning, packing and other details. Men are employed in activities that demand more physical work (Imani, 2019).

Rural youth is often involved in the avocado sector as marketing agents or as transporters. In addition there is increased demand and employment opportunities for skilled professionals in the field of agronomy, ICT, accounting, etc. (Imani, 2019).

3.3.4.2 Nutrition and food security

Avocado is a popular and frequently consumed product in Kenyan households both rural and urban. Being a nutrition dense food product, avocado is a rich source of Omega 3 and Omega 6 fatty acids and proteins. In addition avocado contains 18 of the 22 amino acids including the 8 essential amino acids and it provides consumers with important vitamins, amongst others, vitamin A, B-complex, C and E.

The current rates of consumption of fresh fruits and vegetables in Kenya are estimated at 300g per capita per day. Increasing the availability, accessibility and affordability of avocado in the domestic market has the potential to contribute to nutrition security. In addition the income and employment that the sector generates also contributes indirectly to nutrition and food security.

3.3.4.3 Environmental impact

Large scale, commercial avocado plantation that cover large extensions of land and have access to irrigation water tend to have fairly high impact on the environment. In contrast, small-scale production practices in which avocados are mixed and dispersed throughout the land of farmers makes effective use of limited land and water resources.

3.4 Avocado post-harvest losses

Efforts to reduce losses in the avocado sector must pay adequate attention to the production stage which indirectly has a strong effect on post-harvest losses that occur downstream. However this analysis explicitly focusses on interventions and leverage points targeting losses in avocado once the product has been harvested. The underlying reasoning for this specific choice is that there are a multitude of efforts and investments that are already addressing improved productivity and reducing product loss during this stage.

3.4.1 Critical loss points in the avocado supply system

This section describes the critical-loss points (stages in the avocado supply system were losses are high) and the main causes of these post-harvest losses.

The domestic supply chain suffers most from the highest losses, consumes the largest volumes of avocado, employs the largest number of small-scale farming households and has a strong contribution to SDG's and food system outcomes. Therefore this analysis focusses on the domestic market where the loss reducing potential is highest with the largest impact. A number of the mentioned leverage points for loss reduction that are analyzed here are also applicable to operations of exporters and farmer organizations targeting the export market.

Post-harvest losses occur on-farm, during transport, during storage, at wholesale markets and at retail. Major causes of loss are improper handling, pest and diseases, and product deterioration due to lack of temperature-controlled storage and pre-cooling.

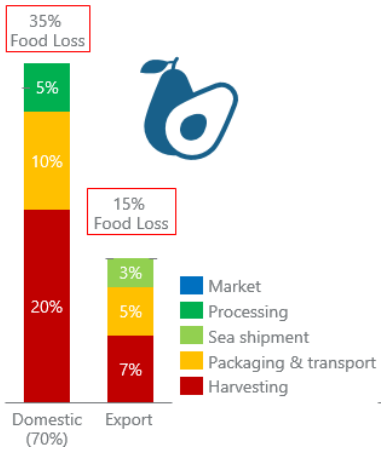

Figure 5 *Post-harvest loss profile for avocado*

As figure 5 illustrates, It is estimated that in the export supply system approximately 15 percent of avocados are lost between the farm and the consumer. For the domestic market approximately 35 percent of avocado's harvested are lost before being consumed. These stark differences can be explained by the fact that measures and investments to minimize losses in the export supply chain are fairly common, whilst that is not the case for the domestic supply chain.

In the domestic supply system, post-harvest losses are predominantly concentrated during the "first mile", after harvest (where losses of up to 20 percent are reported), and an additional 10 percent of losses that occurs during transport and packaging. Part of the avocados that are not suitable for the for the fresh market are also rejected for processing; these losses are estimated at 5 percent.

The actual volume of losses at the market (wholesale and retail) is considered significant but poorly understood (and therefore not presented in figure 5); deteriorated products are often sold at reduced prices and therefore represent an (unknown) economic loss.

The mentioned "first mile" activities (harvesting, packing, transportation and storage) have significant influence on product quality and shelf life. Of the total losses more than 80 percent is incurred in these first stages.

Opportunities to reduce losses generated during first mile activities will be addressed in detail in chapter 4 and 5 of this report. These opportunities include handling and packaging, transportation and storage.

3.4.2 Economic impact of post-harvest losses

To understand the economic impact of post-harvest losses, the analysis looked at the price of avocados at a particular transaction stage and correlated that value to the percentage of loss that was identified for that stage in the food loss profile depicted in figure 5. By matching these variables to the transaction between a "product owner" and "product buyer" the analysis uncovers how losses along the supply system affect different stakeholders.

A small-holder typically has 10 avocado trees, each producing on average 700 fruits (approximately 140kg) per year. Based on prices ranging between KSH 10 to KSH 25 per kg paid by marketing agents to farmers, the farmer hypothetically misses KSH 2.5 to KSH 6 income per kg sold (although most likely not all avocados that are produced are fit for trade). 20 percent loss therefore means an annual income loss for a small-scale farmer of KSH 2800 to KSH 7000. The reported average income from avocado farming in Meru was KSH 40.000 per annum. The losses would represent an average of 12 percent of that income.

Likewise the 10 percent losses that occur during "packaging and transport" represent an economic loss of KSH 2 to 10 per kg traded based on the typical marketing agents' selling price of KSH 20 to local market. When selling to major supermarket outlets and retailers in Nairobi marketing agents have an income loss of up to KSH 45 to 100 per kg.

3.4.3 Leverage points for post-harvest loss reduction in avocado

Leverage points for post-harvest loss reduction have been identified based on the critical loss points and the economic impact analysis. The loss-reducing leverage points correspond to particular stages in the avocado supply system where modifications can lead to reduces post-harvest losses in the entire system, whilst impacting food system outcomes positively.

Leverage points address a particular facet of the supply system and the sector rather than referring to single spot interventions. Leverage points do not exclusively imply specific activities or technological interventions for specific stakeholders but encompass, amongst others, stronger horizontal and vertical integration and sector coordination.

3.4.3.1 Product handling and temperature management

This leverage point addresses a large proportion of the post-harvest losses incurred during handling, storage, transport and marketing. The main quality defects identified in post-harvest losses are bruising (linked to mechanical pressure during handling and transport), spoilage and over-ripening (linked to rapid deterioration). Packing of avocados in large sacks and transporting them over bumpy roads in suboptimal conditions severely affects quality. Adequate packaging has the strong potential to reduce bruising. Additionally, temperature management during the first mile is critically important to diminish the relative rate of deterioration and maintain product quality throughout the supply system. For the case of avocado with a typical shelf life of 40 days under optimal cold storage conditions, respiration/deterioration is increased by about 10-fold under suboptimal conditions (table 8). Storing the product at ambient (generally high) temperature at the beginning of the post-harvest chain strongly harms the quality and reduce shelf life on the market.

Table 7 *Typical effect of temperature on the rate of deterioration of fresh fruits and vegetables (Gross et al.,2016, USDA)*

Temperature	Relative rate of deterioration	Relative shelf life (days)
0°C	1	100
10°C	3	33
20°C	7.5	13
30°C	15	7
40°C	22.5	4

Table 8 shows that lowering the product temperature from 20-30 to 5-10°C for 2 days in the first stages of the post-harvest chain would increase the shelf life on the market by reducing the rate of deterioration. Refrigeration during transport would furthermore facilitate moving the products to the (relatively remote) urban market without reducing shelf life in that market. By combining temperature controlled storage at different stages of the supply chain with packaging solutions that reduce mechanical damage such as bruising damage, the seasonal sales period of avocado can be extended by a few weeks.

Uninterrupted temperature management throughout the supply chain is most effective. This requires pre-cooling (on-farm) and an uninterrupted cold chain, including cooled transport. Temperature management during the first mile (known as pre-cooling) is critical for the product quality throughout the supply chain. For maximum effectiveness, temperature management should initiate immediately after harvest. This implies the use of small-scale, low-tech and energy efficient systems located on or near the farm.

3.4.3.2 Agri-processing and transformation

There is a growing international market for processed avocado products. A small number of processors involved in pressing avocado oil make use of avocados which are considered unsuitable for the export or domestic market. Although these type of processing activities generally operates at industrial scale, there are experiences of farmer organizations that have engaged in this value addition activity.

Readymade, processed avocado products might find a viable export market; domestic market is limited to oil pressing and making avocado shakes. Alternative and innovative product lines can be developed to specifically target the growing export market. However, as mentioned before due to lack of traceability small-scale avocado producers have a hard time accessing the growing high-value export market.

Avocados that are not suitable for human consumption can also be utilized to feed black soldier fly larvae, which can be utilized and transformed in to protein rich animal feed products.

More details on the options to upgrade rejected, lower quality avocado’s into high value products can be found in chapter 5.4

3.4.3.3 Digital innovations for improving market linkage and access to agri-finance

The avocado sector is complex, characterized by many informal transactions and a lack of market information, transparency, fixed buyers and fixed prices. Small-scale farmers are often unable to fully invest in productivity increase, improved agricultural practices and post-harvest management as they are constrained in accessing the high revenue avocado market. The result is a harvest of mixed quality avocados that are sold at low farmgate prices. Digital innovations appear on the market to help smallholder farmers and the value chain actors they interact with to access market information, digitize production records, make supply chain transactions more transparent. Transparency and traceability are increasingly considered as important product information to potential buyers. Kenya has experience with a number of digital applications linking procurement with traceability, digital records and payments, and even access to markets and services (GSMA, 2020).

The vast majority of agri-finance products focuses on the procurement of agricultural inputs for staple and cash crops. Considering the social and financial business case that post-harvest loss reduction represents, there is a strong need to develop customized and tailored agri-finance products that are designed to target capital investments in post-harvest management.

3.4.3.4 Policy and regulatory environment

They key performance indicators that are most cited in the avocado industry are volumes of avocados produced and exported, area planted with avocado, productivity increases, and contribution to GDP. Although this type of indicators are valuable estimates of the growth of the sector they do not provide insights into the inclusiveness, the sustainability and the food system outcomes of the avocado sector (employment generated, living income generated, resilience, volumes of loss, etc.). There are no regulations regarding the handling, transporting and post-harvest management of avocado. As a result the informal market trades avocado in bulk without specific quality considerations leading to loss of valuable and nutritious avocados.

3.4.4 Technology options for post-harvest temperature control

Similar to the case of mango there are a series of technology options for post-harvest temperature control that correspond to different levels and scales of application in the avocado sector.

- Farm-level, evaporative (zero-energy) cooling technologies offer costs-effective post-harvest management interventions that have proven to be effective and provide a good return on investment at farm, co-operative or community level (Manyoso *et al.*, 2018). Evaporative cooling is a relatively low-cost pre-cooling solution that allows to slightly lower ambient temperature and core temperature of the freshly harvested avocados (typically 3 to 5 degrees below ambient temperature). This method is effective because of the significant reduction of respiration degradation and reduction of moisture loss from the product. In the case of avocado it reduces the maturing rate and prolongs shelf-life. A variety of effective technologies exist for this level of application that are affordable for small-scale farmers (Manyoso *et al.*, 2018).
- Medium-scale (containers-sized, mobile, 20 ft) medium-tech solutions that integrate post-harvest handling, aggregation of produce and market linkage platforms are great opportunities for mobile first-mile, cold storage and aggregation. Emerging applications of this technology include storage solutions offered by companies whereby producers pay for customized services, without requiring capital investments.
- Medium-to-large-scale, high-tech cold storage and aggregation centers in logistical hubs such as Nairobi or Murang'a or Mombasa offer opportunities for large-scale farmers, farmer organizations and exporters to aggregate and handle larger volumes. Investments range between 80,000 EUR to 5 million EUR with operational costs depending on energy usage (solar or electricity) and labor costs.

Effective organization of the avocado sector would ideally integrate a complementary mix of the above storage solutions (including refrigerated transport) in order to reduce post-harvest loss to a minimum. All three technologies are proven to be effective. Economic viability of the options depends on the local context. The above analysis focusses on the domestic market and takes into consideration the avocado post-harvest food loss profile (figure 6). Based on these parameters the most suitable and relevant cold storage solution would be the medium scale, mid-tech solution. A cost-benefit assessment of this option is worked out in chapter 5 of this report.

3.5 An overview of the poultry sector

3.5.1 Markets and Policies

A recent report on the poultry sector in Africa calculated that the poultry meat market will increase from its current 5.7 Metric tons to 11 million tons by 2030. In Kenya, the poultry sector produces over 25 000 tons of poultry meat and 1.3 billion eggs per year, jointly valued at KSH 28.5 billion (FAOSTAT, 2017). Per capita Kenyans consume approximately 0.56 kg of poultry meat and 45 eggs per year (FAOSTAT, 2017). It is estimated that 65 percent of Kenyan households raise poultry. The majority are backyard indigenous chicken producers with smaller numbers of commercial layers and broiler farms and only a handful of industrial integrated layer and broiler farms. In numbers: there are approximately 39 million poultry units in Kenya; 20.6 million Kenyans live in households that keep free-range poultry, 3.4 million people live in households who are involved with semi-intensive poultry farming and less than 100.000 people in households that are involved with intensive broiler production (FAO, 2018). The three different poultry production systems are directly aligned with the three food system typologies that have been described in chapter 2. The Kenyan poultry industry is domestic-oriented with less than 1 percent of poultry meat being exported. The poultry sector is comprised of indigenous birds ("Kienyeji"), broilers and Kuroilers ("improved indigenous") and hybrids. The indigenous bird segment is the largest both in terms of numbers of producers and numbers of birds[24]. The sector is extremely informal and disorganized with many individual smallholders, predominantly women, and informal traders who play a

[24] Estimated poultry bird composition in Kenya 2019: 3.9 MN layers (8%), 3.2 MN broilers (7%), 31.6 MN indigenous birds (also referred to as road runners) (68%), 4.0 MN improved indigenous birds (8.5%), 4.0 commercial indigenous birds (8.5%). Source: FAO and Larive calculations (2020).

fundamental role in aggregating birds from smallholder producers after which they are transported and distributed at different market points.

The poultry sector is a priority sector in Kenya. Poultry is mentioned in a series of policies and has been receiving attention and investments from National Government, country governments, multilateral donors, research institutes, NGO's and the like acknowledging the potential to contribute to sustainable livelihoods, poverty reduction, nutrition, food security and gender equality.

3.5.1.1 Domestic market

Approximately 85 percent of the Kenyan poultry flock are sold live at domestic markets (urban and rural). 10-15 percent of birds are sold slaughtered. A limited number of Kenyan companies are involved in commercial-scale poultry production. Those companies integrate poultry production with downstream processing and agro-logistics operations. These larger commercial players supply high-end supermarkets, hotels and restaurants, primarily located around larger commercials hubs such as Nairobi and Mombasa.

Domestic demand for poultry meat is growing steadily, not only in cities but also in rural settings. There is growing demand for quality, safe and nutritious food products by urban middle-class consumers who are increasingly aware and conscious of their food choices. The combined effect of population growth, and increased consumption of poultry meat is expected to drive the market for Kenyan poultry products. Nairobi's consumption is estimated at around 5 million birds per day and continues to grow. Kenyan consumers tend to have a preference for indigenous birds. The price for indigenous chicken is usually higher. There is a large demand for live birds caused by the cultural belief that fresh meat is better and healthier than slaughtered meat.

There is a general absence of market information, transparency, biosecurity, veterinary controls and traceability in the informal poultry sector. Only a small number of poultry farmers are formally organized into producer organizations and have contractual arrangements with industrial processors, marketing agents and buyers. This is likely to change as growing numbers of supermarkets and fast food chains will increase the demand for safe, traceable, processed and packaged chicken meat products.

There are only a select number of poultry producers and processers that comply with the food safety standards that are required in the food and hospitality industry. Kenchic is the largest industrial poultry company in Kenya that integrates production, feed and input supply, transportation, handling and processing following strict regulations, protocols and certification.

Indigenous poultry is predominantly sourced from small-scale and medium-scale farms through marketing agents that play a crucial role in aggregating birds and connecting small-scale poultry producers to markets. Marketing agents offer fairly low prices for chicken at the farm gate and obtain high prices at wholesale and retail. There are few regulations enforced in the informal, indigenous poultry sector (WUR, 2018).

3.5.2 Environmental drivers affecting the poultry supply system

Although there are agro-ecological conditions which are more suitable for poultry production than others backyard poultry farming is practiced across the 47 counties in Kenya (FAO, 2018). Water availability, ambient temperature and altitude are the main environmental drivers influencing the poultry supply system.

Poultry production systems that rely on purchased concentrates and chicken feed are highly dependent on animal feed. Growing demand for poultry products are putting additional pressure on natural resources to satisfy the demand for poultry feed. Local feed production is hampered by a strong competition between food/feed and limited availability of productive land, energy, water and fertilizers (Abro *et al.*, 2020).

3.5.3 Overview of the poultry supply system

An overview of the geographical distribution of poultry producers (smallholder farmers and large-scale producers) is described by the FAO: "Most smallholder farms in Kenya are found in Machakos, Nakuru, Bungoma, Rachuonyo, Makueni, Mwingi, Kilifi and Kitui districts in decreasing order of numbers. The Arid and Semi-Arid Lands districts of Mwingi, Kitui, Machakos, Makueni, Kwale and Kilifi are contiguous and between themselves carry the highest concentration of poultry in Kenya. On the other hand, farmers in Kiambu, Thika, Nairobi, Nakuru, Kisumu and Machakos produce broilers in large numbers. All the high concentrations of commercial layer and broiler farmers are located near provincial urban centers and in the peri-urban areas of the city of Nairobi where access to markets is guaranteed" (FAO, 2008).

3.5.3.1 Agricultural production

As mentioned, the largest volumes of poultry units are sourced from small-scale farmers who raise poultry in their backyards. These production systems generally fall under the rural, traditional, informal and expanding food system typologies as described in chapter 2. Culturally, in Kenyan households women are predominantly the ones engaged in poultry production and they sell their animals to generate an source of economic income. Numerous projects and programs have shown the potential of poultry production to improve livelihoods and economic income opportunities for rural women. Backyard poultry production easily integrates with other farm and off-farm activities, diversifying sources of income and livelihood hence contributing to household food and nutrition security and resilience building.

There are increasing numbers of commercially-oriented small-scale farmers who are organizing themselves in producer organization and investing in production inputs, veterinary services and market linkages through horizonal and vertical supply chain integration. Non-the-less the largest majority of livestock comes from farmers that use poultry as a source of income and supply their families with meat.

A growing number of counties, NGOs and Kenyan banks are offering support to the poultry sector, focusing on improved production and productivity through the use of high quality chicklings, agricultural inputs, veterinary services, specialized housing and handling approaches and others and tailored agri-finance products.

3.5.3.2 Poultry trade, transport and storage

Small-scale poultry producers have difficulty accessing the market. Due to the low volumes of birds they produce and the distances to wholesale markets, smallholders depend and rely on marketing agents who source and aggregate live birds from multiple producers, and transport them in bulk to the wholesale markets and retailers. Animals are transported in challenging conditions, packed in small spaces and exposed to extreme climatological conditions. Animal welfare, animal hygiene and biosecurity are neither regulated nor enforced (WUR, 2018). As a result high levels of mortality are experienced during transport. There is a general lack of cold-chain infrastructure for small-scale poultry producers.

3.5.3.3 Food processing and transformation

Private sector stakeholders from Machakos/Makueni, (Eastern Kenya) Nakuru (Central) and Isiolo (Northern Kenya) all indicated the need for industrial slaughtering to ensure hygienic standards, as there is currently low availability of those facilities. Several players indicate the low supply of birds that results in the production facilities running at low capacity (sometimes 10 percent), causing the facility to run at a loss. Getting a consistent supply of birds to process is essential.

There are examples of poultry associations that have worked effectively with mobile poultry slaughter facilities that can be located near farm clusters and moved from one place to another depending on demand and availability.

3.5.3.4 Wholesale and retail

Nairobi is a key market, especially for indigenous chicken. Given the "close" proximity to Nairobi from Machakos/Makueni, the actors from this region are more likely to supply their birds in a live state. Isiolo has a big potential of capturing the Northern Kenya market. Important indicators showing a growing market include cold chain logistics, investment by breeders and hatcheries, government support and regulations, fast food chains, marketing campaigns by supermarkets and trendsetting small stores and the involvement of some institutions (healthcare, the army). Several larger cold chain suppliers have investment plans for the coming five years[25]. Fast food chains indicate growth, as many Kenyans see the introduction of franchises as a sign of increased prosperity and presence on the international stage (as investment destination). KFC opened in 2011 in Nairobi, now with 22 restaurants in Kenya (June 2021). Others followed: Subway (2013), Domino's Pizza (2014), Pizza Hut (2015) and Burger King (2016).

3.5.4 Contribution of the poultry supply system towards food system outcomes

3.5.4.1 Income and employment

It is assumed that on average 75 percent of rural households in Kenya keep poultry. In some Counties, over 96 percent of the rural households are estimated to keep indigenous chicken in extensive or semi semi-intensive systems. Poultry production is therefore a significant contributor to household income and food security and nutrition (FAO, 2018). The FAO analysis revealed that intensive poultry producers derive approximately 63 percent of their income from poultry production while poultry farmers engaged in indigenous poultry production obtain between 44 and 36 percent of their daily household income from this activity.

The poultry industry has linkages with other sectors of the economy, such as feeds manufactures, hotel industry, and input suppliers. However, due to lack of adequate data on the linkages, the true value of the poultry industry's contribution to the entire economy is usually under-estimated. The industry has the potential to generate higher incomes and transform living standards of its players if appropriate interventions are developed and implemented[26].

3.5.4.2 Nutrition and food security

The poultry sector strongly contributes to nutrition and food security by providing a popular source of affordable and readily animal protein (both meat and eggs) to rural and urban consumers (FAO, 2018). The poultry industry feeds over 80 percent of the rural households in addition to its numerous social and cultural uses that makes it even more popular[27]. Poultry products per unit of uptake provide more protein than other sources of animal meat. It is anticipated that there will be an increase in effective demand of poultry meat as a result of a shift in consumer preference from red to white meat as incomes and health consciousness improve.

WHO recommends the consumption of 50g of protein per day per capita (varies amongst individuals; this is an average). The current food protein availability in Kenya is estimated at 60g per day per capita (FAOSTAT), of which 25 percent is of animal origin. Taking into consideration that a large part of these proteins is from crops with incomplete amino acid composition or limited protein bioavailability and that distribution over income categories is unequal, it is considered important to make more healthy animal proteins available and accessible and affordable; also for poor rural households. From a micronutrient perspective this category off food products is also very important. The highest deficiency micronutrients in low-income countries are Vitamin A, iron and iodine (WHO). Meat is especially rich in Vitamin A and iron. Reducing losses in the poultry supply chain can increase the supply, availability and the affordability of poultry products which in turn can contribute to an increase in consumption and improved nutrition.

[25] Cold Solutions, invested USD 70 million in 2020 and SokoFresh plans to place 400 cold storage units within five years

[26] Integrated National Export Development and Promotion strategy 2018

[27] Integrated National Export Development and Promotion strategy, 2018

3.6 Poultry losses

Systemic approaches to reducing losses in the poultry sector have the potential to structurally contribute to sustainable development goals and positively influence food system outcomes. The Kenyan poultry sector has the potential to contribute to food system outcomes by generating income and livelihood opportunities for stakeholders both upstream and downstream, generating off-farm employment opportunities for young women and men, and improving domestic access, availability and affordability of animal protein for domestic consumers.

Losses in the poultry value chain constitute a source of unattained potential of economic profit within the agri-food sector in Kenya. In this assessment, specific business interventions that have the potential to be successful in both reducing food losses and providing additional economic gains from improved preservation and quality of poultry products have been identified.

Business interventions can be realized at different scales at different locations. Scales range from small-scale (low-to-medium tech), medium scale, to large-scale (high-tech), respective locations vary from the farm level to (urban) logistical hubs, wholesale market places and retail markets. Each level, scale and location requires a tailored management, operations and governance arrangement for the interventions to be effective and to operate profitably and successfully.

Effective loss reducing interventions will require an integrated approach that does not exclusively rely on technological hardware to fix a specific problem. Integrated sector transformation will require a combination of supportive sector-wide policies and regulations with incentives to reduce post-harvest losses, innovative financing and improved collaboration among stakeholders within the sector. Improving traceability and food security throughout the supply chain has a strong opportunity to enhance agro-logistics, market linkages and regulation of the sector.

Increased stakeholder coordination has the potential to positively benefit producers, traders, brokers, wholesalers, retailers, exporters and consumers. The informality in the sector underpins an "unexploited potential to better connect fragmented smallholders to consumers, in more transparent and efficient ways" (FAO, 2020).

3.6.1 Critical loss points in the poultry supply system

This section describes the critical-loss points in the poultry supply system(stages in the supply chain were losses are high) as well as the main causes of these losses.

The supply chain of indigenous chicken suffers from the highest losses, produces the largest volumes of poultry units, employs the largest number of small-scale farming households and has a strong contribution to SDG's and food system outcomes. Therefore this analysis focusses on the indigenous chicken sector where the loss reducing potential is highest and can have the largest impact in terms of farmers' income, livelihoods, employment generation, nutrition and food security.

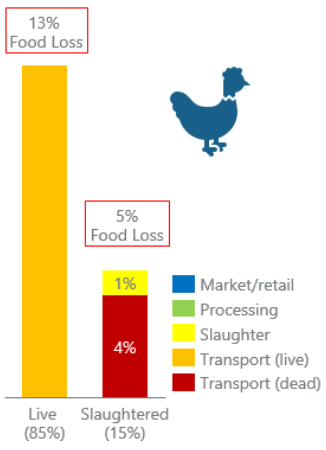

Figure 6 *Loss profile for poultry*

As can be seen in figure 6, poultry losses predominantly occur during transport of live animals. Major causes of loss are improper handling and transporting causing mortality of birds. This analysis looked at information and data from literature reviews, stakeholder interviews and expert opinions to come up with a "conservative assessment" of the losses that occur at the different stages of the poultry supply system, illustrated in figure 6. It is estimated that in the indigenous chicken supply system that accounts for 85 percent of total volume of production of chicken, approximately 13 percent of the animals are lost between the moment they leave the farm and the moment they are sold to consumers. For the case of poultry that is transported in a slaughtered state, losses are approximately 5 percent.

The main cause for this difference is the risk of transporting live birds. Birds are transported in open vehicles with 25-30 animals per cage. On average during transport 10-15 per 100 animals are lost due to stress, suffocation, extreme weather conditions and mishandling. For the slaughtered birds, the most common reason for food loss is contamination and lack of refrigeration after slaughtering. Food safety regulations are currently only enforced for large-scale poultry producers who are required to conduct veterinary checks to ensure product safety.

3.6.2 Economic impact of poultry losses

Although the direct economic impact of poultry losses is carried by the marketing agent who cannot sell 15 percent of the animals he transported, it is evident that the marketing agent includes these economic risks in the business calculations. As a result producers are offered low farm gate prices. From a systems perspective it is important to note that these poultry losses do not only affect the producer and the marketing agent, the economic losses also affect the end consumer who is impacted by higher market prices for poultry products due to reduced availability and accessibility.

3.6.3 Leverage points for loss reduction in poultry

Leverage points for loss reduction have been identified based on the critical loss points and the economic impact analysis. The loss-reducing leverage points correspond to particular stages and factors in the poultry supply system where modifications can lead to reduced losses in the entire system whilst impacting food system outcomes positively. Leverage points address a particular part of the sector rather than referring to single spot interventions. Leverage points do not imply specific activities for specific stakeholders but encompass, amongst others, stronger horizontal and vertical integration and supply chain coordination.

Advanced slaughtering methods can be introduced through large-scale facilities. By aggregating the produce from several producers, small-scale farmers could have an opportunity to access hygienic slaughtering facilities. This will both decrease FLW and increase food safety and product quality. However, with the current low supply of birds, investments in large- scale processing and storage facilities will only become feasible if there is a structural increase of bird production[28]. The existence of multiple projects and private sector initiatives in the sector to make this happen is promising.

A promising solution to make use of the "waste" of poultry is rendering the feathers, blood, and intestines into high-protein flours and oils. These are valuable products for animal feed, thereby increasing circularity and more sustainable livestock production. Partnerships and the engagement of different stakeholders and investors is key to making these interventions a success. Investments in rendering technology are only financially feasible at a very large scale and hence, in the current situation only suitable for the largest industries in Kenya. Dutch experience and know-how in relation to logistical issues and transport of live birds can be relevant for Kenyan-based value chain stakeholders and sector based initiatives.

3.6.3.1 Product handling regulations

This leverage point addresses a large proportion of the losses incurred during handling and transportation of live animals. Currently there are no specific regulations regarding the handling of live animals during transport. Such regulations are meant to set standards for optimum spacing in cages during transportation. Regulations and guidelines would also contribute to biosecurity, animal welfare and food safety.

3.6.3.2 Agri-processing and transformation

Advanced slaughtering facilities and aggregation centers have the potential to introduce efficient and hygienic slaughtering to small-scale farmers. Stakeholders strongly expressed the need for industrial slaughtering facilities and cold chain aggregation centers. Currently there are few of these types of facilities in Kenya that have the potential to ensure hygienic standards and biosecurity. Making sure

[28] Large scale facilities in Kenya handle 1,000 birds per hour whereas industrial poultry facilities in the Netherlands handle 15,000 birds per hour

that there is a constant supply of good quality birds would make these type of processing facilities viable. The existing facilities currently run at low capacity reflecting the inconsistency in the supply system. Horizontal integration of small-scale poultry farmers and vertical integration of supply chain stakeholders is a precondition that would warrant the success of this type of leverage point/ intervention. Growing demand for processed poultry products for the hospitality and food industry will increasingly create viable grounds for investments in industrial slaughtering facilities combined with cold chains.

3.6.3.3 Digital innovations for improving market linkage and access to agri-finance

The poultry sector is complex, and characterized by many informal transactions and a lack of market information, transparency, fixed buyers and fixed prices. Small-scale farmers are often unable to fully invest in measures to increase productivity and improve production as they are constrained in accessing the market and obtain low farm-gate prices. The result is a suboptimal production process that does not guarantee product quality and food safety.

Digital innovations are emerging to support smallholder farmers and the value chain actors they interact with to access market information, digitize production records, make supply chain transactions more transparent and provide important product information to potential buyers. Increasing demands for fair, inclusive, safe and transparent procurement mechanisms, and farm to fork traceability are generating promising digital innovations. Kenya has experience with a number of digital applications linking procurement with traceability, digital records and payments, and even access to markets and services (GSMA, 2020).

The vast majority of agri-finance products focuses on the procurement of agricultural inputs for staple and cash crops. Considering the social and financial business case that a reduction in poultry losses represents, there is a strong need to develop customized and tailored agri-finance products that target capital investments in poultry handling, processing and value addition.

3.6.3.4 Policy and regulatory environment

For the indigenous poultry sector there are currently few regulations, incentives or policies targeting animal losses, animal welfare or food safety in Kenya. Although there is veterinary control there are no regulations regarding handling, transporting, and management of poultry destined for domestic market with a vast amount of loss of valuable and nutritious food as a result.

Effective policies and incentives to invest in quality assurance, animal welfare and food safety have a potential effect in improving availability, accessibility and affordability of poultry meat for local consumers and additionally improving the income of large numbers of rural householders who depend on small-scale poultry rearing activities to sustain their families and livelihoods.

4 Identified business opportunities for food loss and waste reduction

In the Kenyan avocado, mango and poultry sectors many sub-optimal business practices contribute to food loss. Unfortunately it is not always clear why and how these losses occur. This research has contributed to mapping the sectors by identifying the critical loss points. In this chapter details are provided on how this study identified business opportunities that are best suited for reducing food losses in these mango, avocado and poultry sectors.

4.1 Integrated sector transformation for viable business opportunities

Business interventions have proven to be successful in both reducing food loss and providing additional economic gains from improved preservation and quality of fruits. The absence of modern infrastructure, technology and an efficient market are good predictors of the size of post-harvest food losses, and consequently of the unattained potential of economic profits for farmers. Attempts to reduce food loss through a single business intervention are likely to fail. Therefore, it is necessary to apply an integrated sector transformation approach that looks into different components, from production to post-harvest value addition and consumption.

A combination of supportive sector-wide policies, innovative financing and sector transformation strategies must accompany the specific opportunities in agro-logistics and agro-processing in order to effectively reduce the post-harvest losses that have been identified. In the absence of an integrated approach, the investment cost for certain investments will not be commercially viable as the added value that can be realized is minimal. Bundled approaches that focus on multiple and interacting components and are customized to particular contexts (supply chain, geography, stakeholders, target market, etc.) have proven to be the most effective (Farmer income lab, 2018). Two preconditions for success are horizontal integration of farmers' into organizations and aggregated groups and vertical integration of supply chain stakeholders.

Technological innovations might reduce losses but adequate management, operational and governance structures must be in place for them to work well and not only enable a reduction in post-harvest losses but also generate improvements in farmers' income and food and nutrition security (Wangu *et al.*, 2020; Amare *et al.*, 2019; Farmer income lab, 2018).

4.2 Successful business opportunities

In this chapter, both desired integrated interventions and business opportunities are described. *Desired integrated interventions* are impactful solutions to reduce food loss, improve food quality, and improve farmer incomes. An integrated sector development approach is required, with components ranging from interventions from production and good agricultural practices (GAP) to making the market environment conducive for an effective organisation of agro-logistics and agro-processing.

Obviously not all desired integrated interventions are actual business opportunities. For an intervention to be considered as a true *business opportunity* offering a win-win situation for both Kenyan and Dutch stakeholders, the possible opportunity should fulfil three conditions:

1. The intervention once implemented should reduce food loss compared to the current (baseline) situation;
2. The intervention once implemented should generate net positive economic welfare benefits to the sector; and
3. The possible opportunity should meet the requirements of the (Dutch) investors or product suppliers.

A number of business opportunities have been identified which are summarized in figure 7. Details for all business opportunities are provided in chapter 5.

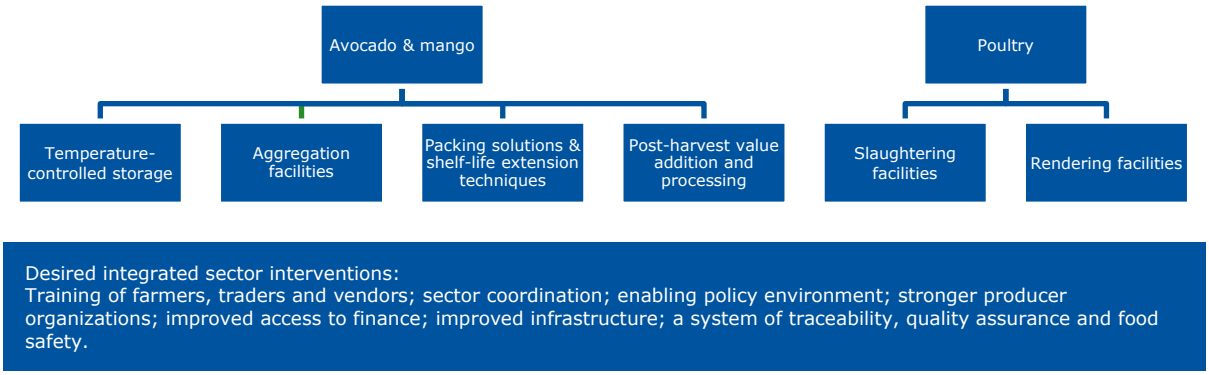

Figure 7 *Identified business opportunities for mango, avocado, and poultry*

4.2.1 Avocado & mango

Integrated sector transformation strategies will require integrating a series of complementary activities to support the sector and make the loss reducing interventions feasible and profitable. The identified desired integrated interventions for mango and avocado are relatively similar which is why they are discussed together. For both sectors, the majority of products are consumed domestically. The domestic value chain has the highest share of food losses and is largely undocumented and unstructured. Not only food losses are a major issue but reduced product quality is also a concern. Critical food losses occur during production and harvesting, transport and storage, and rejected produce meant for the export sector.

4.2.1.1 Desired integrated interventions

The desired integrated sector interventions include training of farmers, traders, and vendors as key actors with the potential to reduce losses significantly (Good Agricultural Practices, product handling, Integrated Pest Management), sector coordination (available market information, formal contracts, market linkages), an enabling policy environment (incentives, regulations), stronger producer organizations, improved access to finance, and improved infrastructure, as well as a system of traceability, quality assurance and food safety.

Rules and regulations regarding the transport of fresh fruits for example would positively impact on the quality of the products. Rules and regulations however have to be feasible and must warrant that they are able to integrate small-scale producers (Amare *et al.*, 2019; Wangu *et al.*, 2020). Regulating and enforcing the use of crates instead of bags to transport avocados and mangos would benefit the sector, however, crates are more expensive than bags and many farmers cannot afford it. Additional support to farmers is often required. For example by giving a subsidy for farmers to purchase crates (see the example in India in 2015[29]) or by financing arrangements with lower interest rates (see also the subchapter 'Utilization of available funding instruments') that enable farmers to make the necessary investments.

4.2.1.2 Business opportunities

The identified business opportunities are those desired interventions that meet the three conditions of reducing food loss, generating a positive economic impact on the sector, and meeting the requirements of (Dutch) investors or product suppliers (see table 8).

[29] State government to give 50% subsidy on crates to farmers - Times of India (indiatimes.com)

Table 8 *Business opportunities avocado-mango based on the selected criteria*

Conditions	Business opportunity			
	Temperature-controlled storage	**Aggregation facilities**	**Packing solutions and shelf-life extension techniques**	**Post-harvest value addition and processing**
Reduce food loss	Yes, the potential to reduce 30-60 percent of transport and storage losses.	Yes, the potential to reduce losses by an estimate of 20 percent.	Yes, the potential to reduce 30-40 percent of transport and storage losses.	Yes, by around 10 percent as it allows for consumption of low-quality products that would otherwise be lost.
Positive economic benefits	Yes, as product quality improves farmers and traders receive a higher price. Furthermore, temperature-controlled aggregation allows farmers to store their products for a few days until the highest price can be received.	Yes, as it streamlines the production process and increases the competitive edge.	Yes, as product quality improves it allows farmers and traders to receive a higher price. These technologies are most relevant for the export supply chain, as packaging facilities usually require large quantities.	Yes, as the largest share of value addition usually takes place at the processing stage. Furthermore, more products can be used (lower quality is acceptable), the shelf-life of the products increases and products can be sold year-round, and there is increased diversity of the products (creating increased demand).
Meet Dutch requirements	Yes for medium- and large-scale operations as many Dutch solutions are profitable for high volume solutions. In that case additional financing is likely necessary (see also 'Utilization of available funding instruments'). Dutch solutions for packing for example are less likely to be feasible for small scale operations on the domestic market.			

4.2.2 Poultry

4.2.2.1 Business opportunities

The Kenyan poultry market is relatively small-sized for Dutch standards. Although small, the quickly developing market is regionally considered the most advanced, and serves as an example for the surrounding countries. Rwandan and Tanzanian poultry companies look to the biggest Kenyan poultry player, Kenchic, to decide which supplier to choose. As Kenchic is one of the only producers adhering to international standards, it serves as the supplier to KFCs in other East African countries as well. Dutch companies considering entering the Kenyan market should realise there is a limited number of large-scale advanced producers but that these companies can serve as an entrance into the larger East African region.

The most promising business opportunities for the emerging Kenyan market and Dutch high-quality manufacturers are slaughtering and processing facilities and rendering facilities (see table 9).

Table 9 *Business opportunities poultry based on the selected criteria*

Conditions	Business opportunity	
	Slaughtering & processing	**Rendering**
Reduce food loss	Limited (in industrial slaughtering) but investments increase efficiency, product safety and hygiene	No but the investment increases the use of non-edible products (30 percent of total live bird weight)
Positive economic benefits	Yes, value addition through processing generally creates the highest margin.	Yes, it turns waste into high-value products for animal feed.
Meet Dutch requirements	Yes. At present only one player (Kenchic) is large enough to match Dutch business interests. Dutch solutions are profitable for high quantities and efficiency. Based on several indicators the demand and production are expected to grow (increasing urban population increase by 2 percent per year to 28 percent, increase in KFC franchises from 0 to 22 in the past ten years).	

4.2.2.2 Desired integrated interventions

There are many desired integrated interventions which are highly relevant for small-scale producers selling directly to consumers (70 percent of meat produced is sold at wet markets[30]). Based on our findings the biggest food losses occur during the transport and sale of live birds due to suffocation, stress, extreme weather conditions (heat stress and freezing), heart failure, and injuries through inappropriate handling. National policy and transport regulations as well as improved biosecurity are considered essential in reducing food loss in the sector. "Both the marketing and the slaughtering processes have many bio-security flaws which could lead to the spread of avian influenza. […] Training in bio-security should be done urgently (FAO, 2008)."

1. Reducing food loss through rules and regulations for transport - for the large-scale producers and processors there are clear rules and regulations. However, most losses occur during the transport of live birds by small- and medium-scale farmers. The main issue with birds slaughtered at wet markets is the transport from the farm to the market (and for unsold birds, the transport back to the farm). Due to overcrowding, birds die because of suffocation, stress, and spreading of disease (poisonous droppings). Reducing the number of birds per cage per truck would significantly reduce food loss within the Kenyan poultry sector. Oftentimes, transport is arranged by private companies that do not own the birds, therefore lack the incentive to reduce the numbers. When transport is arranged by farmers themselves, they often lack knowledge or awareness of the consequence of overcrowding. Increased enforcement of regulations regarding the number of birds in a cage would greatly reduce the number of birds DOA (dead on arrival). As this is not considered a relevant business opportunity for the Dutch suppliers or investors, this option has not been researched in great detail.
2. Improving food security through improved biosecurity - the level of biosecurity can be raised, especially at smaller-scale farms, to ensure product safety. The level of hygiene is strictly monitored at the larger farms where veterinarians are present during the slaughtering process but this is not the case for smaller farms (see Vernooi *et al.*, 2008). For birds slaughtered at wet markets, biosecurity is a major issue to food quality and safety. Improving biosecurity requires more health checks and veterinarians on-site to catch diseases and spoiled products early (before infecting other birds or being sold and consumed). Large-scale players (Kenchic) are known to have invested in this but most small- and medium-scale processors and vendors have not as the formal rules and regulations for veterinary checks are usually not enforced.
3. Other desired sector interventions: training of entrepreneurs in good poultry business practice, and in animal welfare; advanced local feed milling; sector coordination (market information, formalized contracts, market linkages); enabling policy environment, supportive incentives & regulations.

4.2.2.3 The Kenyan poultry sector and the Netherlands

The Dutch poultry sector is globally renowned for its state-of-the-art technology and efficiency. The Kenyan poultry sector is much smaller compared to the Dutch poultry sector. To indicate the size, many Kenyan players consider a facility large-scale when the production is more than 1,000 birds per hour, whereas most Dutch players consider >15,000 birds per hour to be large-scale. According to Dutch companies, very few countries in Africa qualify for Dutch technology. Dutch technology, built for large-scale production, is often not competitive for smaller-scale production as there are many competitors in this segment. According to Meyn, "Kenya is at present at the lower end of the market".

Keeping the growth of the Kenyan poultry sector in mind, introducing advanced technologies such as slaughtering and processing facilities might prove to be a promising business opportunity in the future but is limited with the current levels of production. A promising business opportunity for larger-scale poultry processing is rendering poultry 'waste'. This includes processing the feathers, blood, and intestines into high-protein flours and oils. These are valuable products for animal feed, thereby increasing circularity and more sustainable livestock production. Partnerships and the engagement of different stakeholders and investors is key to making these interventions a success. However, also in this case there are few large scale processing facilities in Kenya that produce a constant and high supply of waste to operate profitably.

[30] (Vernooi *et al.*, 2018)

This leads to the conclusion that there is currently a mismatch between the scale of production of Kenyan poultry companies and Dutch suppliers. Desired integrated interventions (but not considered business opportunities for Kenyan-Dutch private sector collaboration) are improved biosecurity and improved transport of live birds. Dutch knowledge institutes can offer their services to Kenyan stakeholders on product quality and food safety.

Having said that there are indications of a growing poultry sector in Kenya:

- Investment by breeders and hatcheries: IFC is set to invest USD 4 million in Suguna Poultry Kenya to expand breeder and hatchery poultry farms (March 2020).
- Government support and regulations: "East Africa's governments (Kenya, Rwanda, Tanzania and Uganda) have recently passed into law policy changes targeted towards incentivizing the growth of the feed sector in EA. EA's government have removed tax on the raw materials used in the production of animal feed (http://www.blackseagrain.net/novosti/east-african-states-remove-animal-feed-tax-1). Import of raw materials such as cereal bran, premixes, concentrates, soybean meal supplements local production and zero-rating them makes the final product slightly cheaper. These savings are then supposed to be passed on to consumers in the form of more affordable animal protein."
- Fast food chains: many Kenyans see the introduction of franchises as a sign of increased prosperity and standing on the international stage (investment destination). KFC opened in 2011 in Nairobi, now with 22 restaurants in Kenya (anno June 2021). Others followed: Subway (2013), Domino's Pizza (2014), Pizza Hut (2015) and Burger King (2016)[31].
- Marketing campaigns by supermarkets: marketing is increasingly focused on chicken and pork over beef consumption.

[31] When KFC came to Kenya | New Internationalist

5 Analysis of identified business opportunities for each sector

For each of the six identified business opportunities (temperature-controlled storage, aggregation, packaging, post-harvest value addition and processing, slaughtering, and rendering), an important consideration is that one size never fits all. Contextual factors (e.g. local infrastructure and connectivity), socio-economic conditions, cultural values, environmental impacts, sector governance and political climate are all important to consider. In the sections below the identified opportunities are discussed, one by one.

5.1 Temperature-controlled storage for mango-avocado

Installing cold storage facilities is the most effective mechanism to extend the shelf life of mangos and avocados[32]. An overview of the common advantages and disadvantages of temperature-controlled storage solutions is provided in table 10.

> "Because sourcing significant amounts of produce from smallholder farmers take quite some time, farmers and off-takers have to constantly balance the high cost of transportation with the high losses caused by field heat and non-optimal storage conditions. With cold storage, they can aggregate large volumes for 2-4 days without experiencing the food loss that occurs at outside temperatures. Trucks are then utilized at full capacity, reducing the cost of logistics. Reduced food loss and reduced logistics costs, make a very strong business case for cold storage. With this cold chain installed, the door to export markets is opened up, enabling a higher price point for the produce of our farmers."
>
> Paul van der Linden, SokoFresh

Off-the-grid cold chain solutions, mostly powered with solar energy are available. Some farmer organizations collectively buy cold-chain storage, either managed by themselves or by a service provider. Temperature-controlled storage greatly contributes to reducing post-harvest food losses as well as reducing transport costs and emissions.

Numerous on-farm cold-chain solutions have been developed for different uses, and at different scales. Frequently recurring constraints for these type of solutions are: large capital investment that requires full capacity usage year round (possibly for diversifying with different crops) to be lucrative; complicated management of the facilities (especially when purchased and managed by groups of farmers).

[32] CoolbotTM is an innovative producer of affordable cold-chain facilities, whose products are evaluated extensively in field conditions. Ambuko (2017) shows that the shelf life of mangos stored in the CoolbotTM was extended by 23 days compared to mangos that were not refrigerated.

Table 10 *Advantages and disadvantages of various scales of temperature-controlled storage solutions*

Scale	Benefits								Disadvantages					
	Reduces food loss	Improves product quality and safety	A reliable solution to keep products fresh	By extending preservation time, the farmer can wait for a more attractive selling offer	Reduces the need for transport	Robust and can withstand poor weather conditions	Innovative solutions are off-the-grid solutions (solar)	Multi-purpose solutions	Expensive	The capacity size of storage remains limited, making it useful for individual farmers but not for groups	Prone to theft	Require electricity, vulnerable to electricity outages.	Requires (a significant piece of) open land	Maintenance can be complex
Small-scale (e.g. charcoal cooler)	v	v	v	v	v		v			v	v		v	
Medium-scale (e.g. mobile container)	v	v	v	v	v	v	v	v	v		v		v	v
Industrial-scale (e.g. warehouse)	v	v	v	v	v	v		v	v			v	v	v

Note: It is assumed small-scale solutions, although useful, are smaller and less technologically advanced. Therefore, they still offer advantages of preserving product quality, reducing transport, and waiting for a better price but to a lesser extent than high-tech, larger-scale solutions.

5.1.1 Investments and business models

In this section three models of cool/cold storage are compared: 1) small scale cooling technologies (e.g. charcoal cooler); 2) small to medium scale (container-sized, 20 ft) cooling or cold store solutions that offer opportunities for mobile cold storage and aggregation at the smallholder farmer group level; and 3) large, industrial-scale, high-tech cold storage and aggregation centers, feasible for logistical hubs at locations such as Nairobi or Murang'a (see table 11). Examples of experiences and business cases currently implemented in the sector are shared as illustrations of what is possible in terms of technology.

Table 11 *Estimated operational models for small, medium and large-scale cold storage facilities*

	Small-scale	Medium-scale	Industrial-scale
Description	Charcoal cooler[33] Open source technology, locally sourced materials	Containers at farmer locations. Can be solar-powered	Warehouse and logistics service provider
Size	2x1.5x1.5 m or larger	20ft container	15,000 m^2 building
Volumes	Small	5 MT (12-24 pallets)	Unknown
Temperature	Limited cooling	+2 to 12 C. Humidity control with relative humidity of 85-95 percent	+26 to -40 C
End-market	Local/regional	Currently export, in the future domestic	Export (mainly EU)
Location	On or near smallholder farms, possible off-grid. Works best in a region with an air humidity of <30 percent.	Near smallholder farms, e.g. Makueni county	Regional (county-level), e.g. Tatu City, Nairobi
Operational model	Buy (EUR 500-1,000)	Lease (USD 750/month/container or KSH 1/kg/day)	Lease (prices unknown)
Ownership	Farmer	Company	Company
Investment (EUR)	150 to 1,000[34]	SokoFresh: 22,000 including import, taxes etc. Expected to decrease by 20 percent through local sourcing and economy of scale.	5 to 60 million, depending on the size and technological requirements[35]
Estimated energy usage	0	30-60 kWh or solar-powered with thermal energy storage (36 hours)	Unknown, can be solar powered with a backup generator
Electricity price/kWh[36] (EUR)	N/A	0.15	0.15
Labour costs (EUR/day)	5-8	5-40	5-40
Example (company)	-	SokoFresh, ColdHubs	ColdSolutions
Success factors of the examples	Suitable off-grid, affordable for small-scale farmers	Locally applicable, attainable for smallholder farmers, solar-powered	Financing through DFI investors, suitable for multiple products
Picture (example)			

An important consideration when setting up cold chain facilities is the condition in which the product was harvested (variety, ripeness, temperature, the time before entering cold storage) and delivered at the facility, and creating a controlled environment with regulated temperature, CO_2 levels, humidity, and ethylene. Especially mango and avocado ("living products") require a high number of factors to be controlled. Furthermore, the purpose of storing the product is important: which end-market, storage duration and the transport plan. Cold storage of fruit requires knowledge and management skills.

Because the harvesting season for avocado and mango extends around 4 months of the year, it becomes essential to use the storage infrastructure for other purposes during the remaining period of

[33] (Ndombi, J and Schripsema, A 2015)
[34] Charcoal Cooler | Engineering For Change
[35] Cold Solutions announces KSH 7.5 billion investment in Kenya – Cold Solutions East Africa
[36] Kenya electricity prices, December 2020 | GlobalPetrolPrices.com

the year in order to recuperate costs. However, different agricultural products require different cooling conditions; therefore, combining products must be done with careful consideration of how the products can influence one another (e.g. the ripening process).

Finally, the cold chain investment requires a reliable fleet of temperature-controlled trucks. Cold-chain facilities can maintain the quality of products but factually require uninterrupted cooling throughout the chain. To ensure the relevance of cold-chain facilities, inputs used on-farm and means of handling the products need to be up to standard. To achieve these standards, farmers need to have increased knowledge of the requested quality standards, harvest management and post-harvest handling.

Cool/cold storage is essential for all actors along the supply chain as product temperature affects product quality from farmer to retailer. Farmers can benefit from on- or near-farm cool storage (e.g. charcoal storage or containers) by extending the shelf-life by several days, therefore enabling farmers to wait for a better price from buyers, rather than selling whenever the buyer finds suitable. Traders and exporters can benefit from on- or near-farm cold storage by reducing their transport costs, as they can drive full trucks only once every several days. Larger-scale farmers, traders and exporters benefit from industrial-sized cold storage, as it ensures high quality of product to meet the standards of lucrative markets in urban areas or abroad. A selection of notable players in the cold storage sector include:

- Cold chain players operating in Kenya, include SokoFresh, Cold Hubs (operating in Nigeria but interested in Kenya), Cold Solutions, Big Cold, Inspirafarms and Alpha;
- Dutch private sector companies that could potentially be of interest include Cool Green Solutions, Celtic Cooling, Geerlofs, Kloosterboer, Adheerst and Coolfinity; and
- Relevant initiatives include the One Acre Fund, Kigali Cooling Efficiency Program, UKAID (DFID), Global Cold Chain Alliance (GCCA), Atradius, and Cold Chain Assessment Initiative.

5.1.2 Example of a business case: SokoFresh

SokoFresh cold storage being assembled in Makueni (Source: SokoFresh Instagram)

SokoFresh provides cold storage as a service via a lease construction to (small-scale) East African farmers (see table 8). The enterprise started three years ago as a start-up. SokoFresh provides solutions for horticulture value chains such as mango and avocado. The goal of the company is to improve market linkages while creating the highest production value for the farmer.

Table 12 *SokoFresh services*

Farmers/traders	Wholesalers/exporters
Store your produce nearby for multiple days without loss of quality	Aggregate produce conveniently in a controlled environment, manage to ripen and avoid produce damage
No risky investments - pay for storage on a per kg per day basis	Reduce your logistical costs with full trucks and improved planning
Link to buyers and receive orders through SokoFresh's market linkage platform	Pay for what you need without large capital investment.

The company works with Ecozen Solutions, an Indian party providing the technology, which has been developing the technology for the past five years. At present, SokoFresh has three units (20ft containers storing 5 MT of produce). The containers are solar-powered and have thermal energy storage, lasting 36 hours. The containers are semi-mobile and are moved two or three times a year to

ensure capacity utilization by being at the right location during harvest times (e.g., four months avocado, four months mango, four months French beans).

The containers are rented out for a monthly fee of USD 750. This is an attractive option for larger companies as it reduces their transport costs and emissions significantly. Rather than driving to the smallholder farmers twice a day, they can visit the container every three days. A daily rate is also available: 1 KSH/kg/day. The cost of installing each container is EUR 22,000, including imports and taxes. SokoFresh expects these prices to be reduced by 20 percent over time due to local sourcing and tax exemptions.

"Our ambition is to deploy 400 cold storages in the next 5 years, leading to an increased income for 35,000 farmers, 3,000 new jobs in rural areas and 37.500 tCO2eq prevented annually. We are currently scaling up our cold storage capacity in Kenya. Furthermore, we've started to develop a farmer-centric market linkage platform to provide smallholders with choice and support in who they sell to. At this moment we are also starting a pilot with farm-level value-adding processing by setting up a solar-powered avocado oil production line. Our goal is to minimize losses and maximize the value of the harvest farmers. If done right, the combination of cold storage, processing and market linkage will let us achieve our goal. By offering all this through a risk-free 'as-a-service' model, every smallholder will be able to afford it".

Paul van der Linden, SokoFresh

5.1.3 Example of a business case: ColdSolutions

ColdSolutions is East Africa's leading temperature-controlled storage and logistics service provider. Cold Solutions Kenya Limited is a portfolio company of ARCH Cold Chain Solutions East Africa Fund, a private equity fund advised by ARCH Emerging Markets Partners Limited (ARCH). Their team has been studying the value chain for over 2.5 years and works in various sectors (including agriculture and poultry). The temperature-controlled storage ranges from 20° C to -40° C. The company has planned to "develop a total installed estimated capacity of over 100,000 pallets across East Africa to serve the production and distribution needs of local, regional, national and international clients offering a full complement of warehousing and logistics services".[37] ColdSolutions constructs storage spaces and works with a renting model. Their tariffs are lower than renting a reefer.

According to ColdSolutions, the Kenyan market currently relies strongly on reefers, as the cold chain infrastructure has not been developed yet. "Currently, there's very limited temperature-controlled logistics in the whole of Eastern Africa." The main barrier to development is the amount of capital needed. The two largest cold storage companies in Kenya are Big Cold (restaurant segment and hotels) and Alpha (a subsidiary of SSSL). Both companies use 70 percent of their capacity for seafood and rent out the remaining space. Where SokoFresh constructs small-scale cold at farm level, ColdSolutions builds industrial-sized storage usually in an urban environment. By combining and aggregating various products from different sectors, they smooth out seasonality, to operate at full capacity year-round ensuring a profitable business.

ColdSolutions sees a lack of investment in the East African sector because private sector players are unwilling to invest in a higher risk market, such as Kenya. Furthermore, ColdSolutions has seen several government-run initiatives fail.

ColdSolutions is DFI-funded and both financially and development-goal motivated. They see a very successful financial business case in Kenya while also contributing to post-harvest loss reduction, gender equality (many smallholders are women), increased farmer income, increased health and safety. Estimating the market size for the Kenyan cold chain segment is very difficult, but with over 400,000 smallholder farmers and anecdotal evidence of the high demand, ColdSolutions is highly confident of the potential.

[37] Cold Solutions East Africa

Second-hand reefers: a short-term but less sustainable cold storage solution

A reefer (short for refrigerated container) is a mobile container with a refrigerator attached to it. It is mostly used for transporting items that need to remain cool long-distance, usually on ships. Reefers no longer used by shipping companies are sold second hand. On average, a 20 feet reefer fits 11 pallets, a 40 ft reefer fits 23-24 pallets. One pallet fits on average roughly 800kg of fruits although mango and avocado are heavier than average fruits. A pallet of meat weighs 1.2 MT. A rough estimation would be for a 20ft container to contain 9.9 MT of avocados or mangos or 13.2 MT of poultry meat. A critical condition for using a reefer is that the product is already cooled before entering as the reefer itself does not have the power to cool down a product. It can only keep it stable at a low temperature. Buying a second-hand reefer costs approximately USD 4,000 (20ft container) to USD 10,000 (40ft). It is also possible to rent reefers with costs estimated at USD 1,400 per week for 24 pallets (which comes down to USD 58 per pallet per week). Investment risks include breakdown of equipment, a short 'life expectancy', transport from Mombasa to the location of the farm, and more expenses in the long run compared to permanent cold storage. Reefers, while cheap and easy to use for farmers, are inefficient and unsustainable.

5.1.4 Feasibility and sustainability

Cold storage contributes to extended shelf-life, thereby contributing largely to food loss prevention and reduction and sustainable production. In the case of small- or medium-sized temperature-managed storage facilities, farmers deliver their produce to the cold storage facility, where traders or exporters pick it up every two to four days instead of every day or even multiple times a day. This reduces CO_2 emissions.

The environmental impact of a cold chain highly depends on the location, capacity, and energy efficiency of the facility. Kenya has one of the highest connection rates to the power grid in Sub-Saharan Africa. The main energy sources are hydroelectric power (50 percent oil (33 percent) and geothermal (16 percent)[38]. With hydroelectric power and geothermal power being renewable energy sources, the use of electricity in the country is considered relatively sustainable.

For medium scale temperature-controlled storage facilities, it is likely necessary for farmers to integrate horizontally and form groups or associations to bear the investment and operational costs together. The need for the strengthening of farmer groups has been indicated by several interviewees, including representatives of the Makueni food processors society, the Department of Agriculture, irrigation, livestock and fisheries in Machakos, a representative of the University of Nairobi, and a representative of the Murang'a Avocado farmers co-op union. There have been several examples of successful farmer groups, including the Kyeko Self Help Farmer Group. There have been examples of groups failing to manage a communal facility. The best way to group farmers and the conditions under which group management would be successful was beyond the scope of this research.

5.1.5 Potential food loss reduction

Temperature-controlled technology could reduce food losses that occur during transport and storage of by 30 to 60 percent. The actual food loss reduction is highly dependent upon the management context, an uninterrupted cold chain, the scale of the facilities, the quality of the products, the circumstances under which the products are harvested (or grown, in the case of poultry), and the reliability of the power grid.

[38] National Energy Grid of Kenya - National Electricity Transmission Grid of Kenya - Global Energy Network Institute - GENI conducts research and education on: renewable energy resources interconnections globally, world peace, stable sustainable development solutions

5.1.6 Cost benefit assessment of container-sized cooling solution

5.1.6.1 Medium-scale container cooling facility for avocado

To provide an overview of the cost benefit relation of cooling technologies for post-harvest loss reduction, it was decided to focus on the medium scale option that was coined as a viable option to aggregate and store fresh produce at a local level, for example serving an urban market. This particular example focusses on the case of avocado.

For this costs benefit analysis the assessment looked at the following intervention:
a small-scale cooling facility providing a service that links farmers to national urban markets such as Nairobi (a 20-ft container that cools the product during 1 day in a collection centre):

- Cold conditions will largely slow down respiration/quality degradation compared to storage at atmospheric conditions (typical 50 to 80 percent slower), which will increase storage life in the remainder of the chain, most relevant at the market/point of sales;
- A 20ft container has a cubic capacity of 28m^3. This volume however should not be completely filled since (cold) air circulation around the product is essential for (rapid) cooling down. Therefore the practical capacity is estimated at 5MT produce per day. The total season length is 6 months (March-September). Thus, the total annual volume stored is estimated at 900MT.
- Earning potential comes from savings further along the chain, especially increased quality and reduction of losses in the market. We assume here a total of 5 percent loss reduction due to the container cooling facility. Based on agents' reference selling price around KSH 20 (€0.16) per kg the total value addition is estimated at: 5 percent x 900,000 x 0.16 = €7,200 per year.
- Total costs of operation of the cold storage facility are estimated at:
  - Depreciation and maintenance: a typical price for a used 20ft container is €5,000. Based on that we estimate total costs of depreciation and maintenance of around €2,000 per year.
  - Energy use:
    - Cooling down:
      Energetic efficiency: COP ≈ 0.9. In ambient temperatures 20 to 30°C and product temperature ranging from 25 to 5°C (during cooling down) the electricity power consumption of the cooling unit for cooling down the product is about 90 percent of the amount of heat removed[39].
      Based on specific heat of 3kJ/(kg °C) for avocados[40], the total energy use for cooling down by 20 degrees comes to 3 x 20 x 0.9/3.6 = 15 kWh electricity per ton product. Thus, cooling down a load of 5 ton costs 75kWh electricity.
      With a typical cooling capacity of 7 to 8 kW, we estimate (also taking into consideration heat influx from the outside) that the unit will operate for 12hrs at max (8 kW) power per day.
    - Cold keeping: When the product has been cooled, typical cold keeping power use is 4kW per 20ft container.
    - Total energy use per 24 hours: 12 hrs x 8kW + 12 hrs x 4 kW = 144 kWh per day.

Total energy costs for electricity, based on a price of KSH 19 per kWh[41], are estimated at KSH 19 x 144 = 2,736 (about €22) per day, that is about €4,000 per operational period of 180 days per year. Conclusion: the earning potential is comparable or slightly higher than the total depreciation, maintenance and energy costs (€7,200 – 2000 – 4000 = €1,200 per annum).

An additional benefit may come from evaporative cooling at the farm. Evaporative cooling is a relatively low-cost solution for slightly lowering room temperature (typically 3 to 5 degrees below ambient temperature, Manyozo et al, 2018). For multiple days storage this method is very effective, because of the significant reduction of respiration degradation and reduction of moisture loss from the product. However the capacity for cooling down is very small and this technology is only recommended if products stay more than 1 day at the farm.

[39] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_04_03_02.html
[40] https://www.engineeringtoolbox.com/specific-heat-capacity-food-d_295.html
[41] https://www.globalpetrolprices.com/Kenya/electricity_prices/ lists a price of KES 18.95 per kWh for business in December 2020

Remarks:

- The benefit of improved product quality is not taken in consideration. When higher value markets can be served (like supermarket outlets and groceries in Nairobi) the earning potential becomes much higher.
- Further benefits of the cooling container come from extending the seasonal period of sales. The avocado can be kept in refrigerated storage for a few weeks. Assuming that the avocados trading price is increased by 25 percent, the added value of one container load (5 Mton) is estimated at 25 percent x €0.16/kg x 5,000kg = €200.
- The costs of depreciation and maintenance associated with the avocado produce can be reduced by storing other products outside the avocado season.

5.1.6.2 Climate impact analysis of the medium-scale container cooling facility

This technology option has multiple effects on climate impact of food supply:

- Using energy for cooling results in additional emissions.
  Production and supply of electricity in Kenya induces 0.66 kg CO_2-eq. per kWh (IGES, 2020). For the annual electricity use (144 x 180 = 25,920Wh) this means total emissions of 17,107 kg CO_2-eq.
- When assessing at the product's climate impact the following was considered: the greenhouse gas emissions of agricultural production and post-harvest operations are allocated to the marketed food products. This implies that in case of losses, the emission related to generating the lost produce are added to the marketed products. Although the number of studies on climate impact of food production is rapidly increasing, still very few data are available on products like avocado. None was found for avocados from Sub-Saharan Africa. Therefore we assume the average of a typical value for fruits and vegetables in Sub-Saharan Africa (given by Porter *et al.*, 2016) and a typical value for avocado's presented by Frankowska *et al.* (2019): 0.75 kg CO_2-eq per kg crop (off-farm).

Taking into consideration 10 percent loss that takes place between farm and market, climate impact per kg avocado on the market is 0.85 kg CO_2-eq per kg (including, relatively small, impact due to transport). Total savings when going from 10 percent losses to 5 percent losses equals: 0.85 kg CO_2-eq/kg * 5000 kg/day * 180 days * 5 percent = 38,250kg CO_2-eq. In summary, the total emission reduction effect is more than twice the extra emission induced by the intervention.

5.1.6.3 Potential limitations of solar-panelled containers

Increasingly solar systems are propagated as alternative to using grid electricity, not only because of the contribution to eco-sustainability but also because it makes the system less sensitive to of grid electricity interruptions. Solar power has a positive business case, however it may significantly increase the total payback time. The calculated demand of 8kW power would require a significantly larger area of solar panels than the roof area of a 20ft container: around 6x the container area to generate the 144kWh per day. This would make the container less mobile. Another challenge comes from the fact that the product cooling down period will cover (part of) the night, so next to solar power generation either grid electricity or a power buffer is needed.

5.1.6.4 Medium-scale container cooling facility for mango

This specific case refers to a 20-ft container that cools the mango during 1 day in a collection center before it being transferred to a urban wholesale market or agri-processing facility:

- Cooling will largely slow down respiration/quality degradation compared with storage at atmospheric conditions (typical 50 to 80 percent slower). Increased storage life in the remainder of the chain reduces losses at the market/point of sale.
- A 20ft container has a cubic capacity of 28m^3. This volume, however, should not be completely filled, since (cold) air circulation around the product is essential for (rapid) cooling down. Therefore the practical capacity is estimated at 5MT produce. The total length of the mango season is 6 months (July to December). The total annual volume stored is estimated at 900MT[42].

[42] Utilizing the storage solution for another agricultural product in the remaining months of the year will generate larger revenues

- Earning potential of this cooling solution comes from increased product quality and reduction of losses further along the chain in the market. If the cooling solution is capable of reducing total losses by 5 percent, the technology's earning potential (based on agents' reference selling price of around KSH 35 (€0.28) per kg) is estimated at: 5 percent x 900,000 x 0.28 = €12,600 per year.
- Total costs of operation of the cold storage facility are estimated at:
  - Depreciation and maintenance: A typical price for a used 20ft container is €5,000. Based on that we estimate total costs of depreciation and maintenance around €2,000 per year.
  - Energy use:
    - Cooling down:
      Energetic efficiency: COP ≈ 0.9 (in ambient temperatures 20 to 30°C and product temperature ranging from 25 to 5°C (during cooling down) the electricity power consumption of the cooling unit for cooling down the product is about 90 percent of the amount of heat removed[43]).
      Based on specific heat of 3.8kJ/(kg °C) for stone fruits[44], the total energy use for cooling down by 20 degrees comes to 3.8 x 20 x 0.9/3.6 = 19 kWh electricity per ton product. Thus, cooling down a load of 5 ton costs 95kWh electricity.
      With a typical cooling capacity of 7 to 8 kW, we estimate (also taking into consideration heat influx from the outside) that the unit will operate for 14hrs at max (8 kW) power per day.
    - Cold keeping: When the product has been cooled, typical cold keeping power use is 4kW per 20ft container.
    - Total energy use per 24 hours: 14 hrs x 8kW + 10 hrs x 4 kW = 152 kWh per day.

Total energy costs for electricity, based on a price of KSH 19 per kWh[45], are estimated at KSH 19 x 152 = 2,888 (about €23) per day, that is about €4,200 per operational period of 180 days per year. Conclusion: the earning potential is comparable or significantly higher than total depreciation, maintenance and energy costs (€12,600 – 2000 – 4200 = €6,400 per annum).

Remarks:
- The benefit of improved product quality is not taken in consideration. When higher value markets can be served (like supermarket outlets and groceries in Nairobi or export markets) the earning potential becomes higher.
- Further benefits come from extending the seasonal period of sales. The mango can be kept in refrigerated storage for a few weeks. Assuming that the mango trading price is increased by 25 percent, the added value of one container load (5 Mton) is estimated at 25 percent x €0.28/kg x 5,000kg = €350.
- The costs of depreciation and maintenance associated with mango can be reduced by storing other products beyond the mango season.

5.1.6.5 Climate impact analysis and tradeoff

The intervention has multiple effects on climate impact of food supply:
- Using energy for cooling results in additional emissions.
  Production and supply of electricity in Kenya induces 0.66 kg CO_2-eq. per kWh (IGES, 2020). For the annual electricity use (152 x 180 = 27,360Wh) this means total emissions of 18,058 kg CO_2-eq.
- In product climate impact assessment, the greenhouse gas emissions of agricultural production and post-harvest operations are allocated to the marketed food products. This implies that in case of losses, the emission related to generating the lost produce are added to the marketed products. Although the number of studies on climate impact of food production is rapidly increasing, still very few data are available on special products like mango in Sub-Saharan Africa. Therefore we adopt the average for fruits in Sub-Saharan Africa given by Porter *et al.* (2016). Taking into consideration 16 percent loss between farm and market (figure 1), climate impact per kg mango on the market is 0.48 kg CO_2-eq per kg (including, relatively small, impact due to transport).

[43] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_04_03_02.html
[44] https://www.engineeringtoolbox.com/specific-heat-capacity-food-d_295.html
[45] https://www.globalpetrolprices.com/Kenya/electricity_prices/ lists a price of KES 18.95 per kWh for business in December 2020

Total savings through 5 percent loss reduction: 0.48 kg CO_2-eq/kg * 5000 kg/day * 180 days * 5 percent = 21,600kg CO_2-eq. Summarizing, the total emission reduction effect is significantly higher than the extra emission induced by the intervention.

5.2 Aggregation of mango-avocado

Closely related to temperature-controlled storage is aggregation. Aggregation contemplates the sorting, grading, and combining volumes of the same product from different producers.

> "Aggregation is the only way to make farmers make more money from their produce, not forgetting the preservation part where the mangoes do not go bad as quickly as they would without the cold storage in these facilities. Aggregation creates a more direct link between producers and the end market. It also ensures that prices are controlled and stable at a reasonable rate. When traders go to the farms directly to buy mangoes, they make deals that reduce the farmers' bargaining power. For example, they buy mangoes for as low as KSH 3-5/mango in bulk and transport them the wrong way (hired pick-ups/motorbikes in sacks). When they get to the market, a good proportion of the mangoes are spoilt but the traders still make a profit because they sell the mangoes for KSH 30 and above. In fact, in some markets, mangoes retail at KSH 60/mango. So there is a loss of mangoes and unfairness to the farmer. With aggregation, this is eliminated!".
>
> Dr Jane Ambuko (University of Nairobi)

There are many innovative and user-friendly solutions for sorting and streamlining production in the Netherlands that are feasible for Kenyan larger-scale producers to give the sector – especially when related to products destined for the export market - a more competitive edge. Several Dutch players have developed turnkey solutions for the entire process of storage, aggregation, and packaging.

5.3 Packaging of mango-avocado

Packaging can greatly improve product quality and reduce losses. Similar to cold chain facilities, packaging is not a standalone solution as it is most effective in combination with other interventions, most notably storage and aggregation. The avocado and mango supply chain would greatly benefit from the combination of advanced packaging and shelf-life extension techniques.

Good packaging is essential in preserving the quality of a product. Without it, the product is more vulnerable to bruising, humidity (rotting), sun damage, and falling off trucks. The individual products are protected during transport and the storage of products in a constant environment. Packaging consists of different stages and varies for the domestic and export value chain (figure 8).

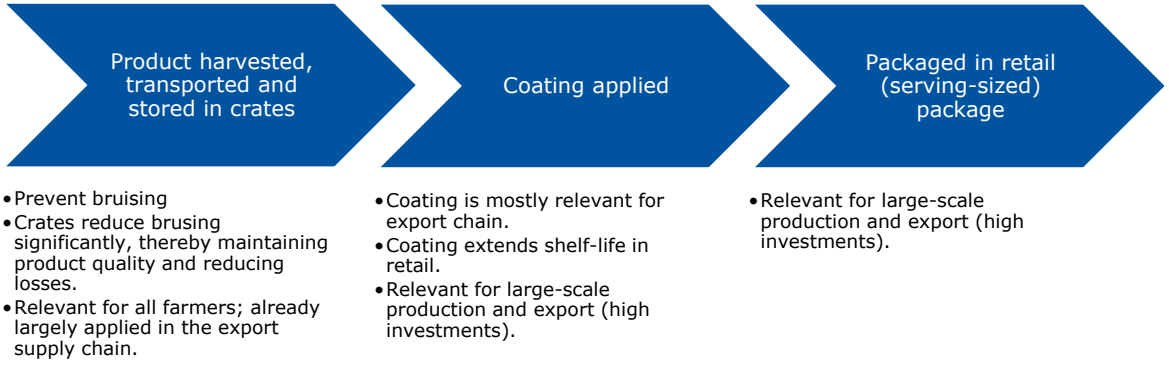

Figure 8 *Packaging solutions include crates, coatings and serving-sized packaging*

5.3.1 Crates

Many farmers, especially small- and medium-sized, load piles of avocados or mangos, lose or in large bags in pickup trucks or large bags causing severe damage to the fruit. The quality of products can be preserved through the use of crates (made from plastic or bioplastic). Crates are a more common practice in the export chain but are not often used by smallholder farmers supplying the domestic market. Crates can be used multiple times and could be considered sustainable as they are reusable.

5.3.2 Coatings

The shelf life of fresh food products such as mango and avocado can be extended by applying protective coatings. For the coating to be most effective, several conditions must be in place. This includes adequate infrastructure (packaging, transport and storage facilities that do not lower the quality of the product), formal contracts and increased awareness amongst farmers regarding quality standards. At present, this food loss reduction intervention is mostly relevant for the export chain.

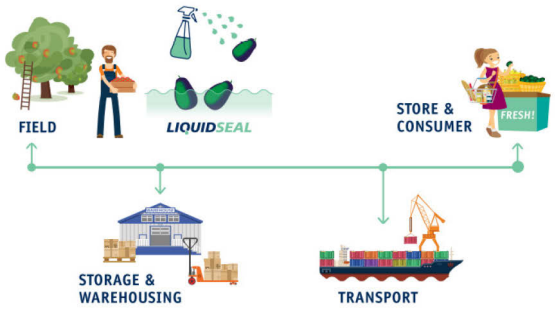

Figure 9 *Liquidseal process of extending product shelf-life through coatings*

An example of an innovative packaging solution comes from the Dutch company Liquidseal (see figure 9) that offers extremely thin biodegradable coating for avocado and mango, preventing fungus, dehydration and overripening. Coatings reduce food loss in western retail outlets with 50 percent (from 6 percent to 3 percent loss) by extending shelf-life by one week. Coating solutions prove particularly effective for fresh products that are exported by sea freight.

5.3.3 Packaging lines for retail

Packaging lines are essential for export to protect products from bruising, moisture and pests and diseases. At present, there are an estimated 20 packaging factories (pack houses) in Nairobi (estimate by MAVOK). In rural areas these facilities are less present. Currently in Kisii and Nyamira for example there is a lack of proper packaging of avocados, with the majority of producers loading avocados into pick-up trucks contributing to the loss of significant quantities.

> "Most often vertically integrated with exporters, packers procure and package a 4 kilogram (kg) carton of avocados at a cost of about US$ 4.10. An additional US$ 1.60/carton is required for shipping to Europe by sea in a reefer. With the import price fluctuating around US$ 7-8/carton, the supply chain overall is profitable. This situation was enabled by government-led infrastructure investments, followed by private-sector investment in reefers, which helped to reduce transport costs versus expensive air shipments. Once this tipping point of profitability was reached, investments started to naturally flow into the sector." Report Kenyan Avocados: Connecting to High-value Export Markets, by World Economic Forum, based on interviews.

The Netherlands is home to many large-scale companies active in the logistics and packaging industry that provide packaging solutions in line with strict regulations for importing exotic fruits into the EU. Companies include for example TFC, Clondalkin Flexible Packaging Group, LC Packaging, and Oerlemans Packaging, FruitMasters, Dutch Pack, Remmert Dekker, VPK Group.

Various types of material can be used for packaging, ranging from plastic (crates or per-serving packaging) to cardboard (retail package). Cardboard has the advantage of being easier to recycle, and therefore considered more sustainable. However, the costs for cardboard packaging compared to plastic packaging is 3 to 5 times more. For example, cardboard packaging for a set of two or four avocados costs EUR 0.03-0.07.

5.3.4 Investment and business model

There are several considerations for investment in packaging facilities for mangos and avocados which are summarized in table 13.

Table 13 *Estimated operational models for small, medium and large-scale packaging facilities*

	Small-medium scale packaging facilities	Large-scale packaging facilities
Description	Crates, boxes	Large-scale packhouse facility
Volumes	Small volumes	Large volumes, >100MT/day
End-market	Domestic market	Export market
Location	From smallholder farmers to medium-sized farmers to local traders and wet markets	Regional, logistical hubs
Operational model	Crates can be supplied by traders to the farmers (e.g. lease model or a deposit) or purchased by a farmer (cooperatives) themselves	Producers supply their products to the packaging facility, where they are quality-checked, sorted, washed, waxed, pre-cooled and packed in cartons
Ownership	Investments to be made by farmers or traders	Investments made by investors or exporters
Investment (EUR)	Unknown (less relevant for Dutch companies)	Packhouse equipment – KSH 60 million
Operational costs	0	Packers procure and package a 4 kilogram (kg) carton of avocados at a cost of about US$ 4.10[46]
Estimated energy usage	0	Unknown
Labour costs (EUR/day)	N/A	EUR 5-10
Example (company)	SokoFresh	Liquidseal, packhouse in Nairobi (Maersk)
Success factors of the examples	Cheap, affordable for farmers and traders, high impact on improving product quality and reducing losses	Efficient, economy of scale, essential to meet high export standards
Picture (example)		

5.3.5 Feasibility and sustainability

Improved packaging and storage facilities contribute to reducing the environmental impact of avocado and mango production. They are able to do this by reducing losses, whilst preserving the quality of the product (less chance of bruising or rotting). The actual impact on the environment depends on the technical design, materials and efficiency of the storage facility and the packaging solutions. For

[46] Enabling Trade – From Valuation to Action - Reports - World Economic Forum (weforum.org)

packaging, cardboard is easier to recycle but more costly. Crates can be made out of bioplastic or other forms of biodegradable or recycled plastics.

Energy utilization also depends on the efficiency of the storage and packaging facility and the source of energy. This can be either through solar panels or by linking to the national power grid. Kenya has one of the highest connection rates to the power grid in Sub-Saharan Africa. The main energy sources are hydroelectric power (50 percent), oil (33 percent) and geothermal (16 percent)[47]. With hydroelectric power and geothermal power being renewable energy sources, this is considered relatively sustainable.

5.3.6 Potential food loss reduction

Improved packing and storage have the potential to reduce food losses incurred due to poor handling and storage by 30-40 percent. This depends on circumstances (climate, temperature and humidity) as well as product handling and behavioral factors. Technologies to extend shelf life, such as coating, have the potential to reduce food losses in retail in Western supermarkets by 50 percent (from 6 percent [48] to 3 percent).

5.4 Post-harvest value addition and processing of mango-avocado

Processing allows for the extension of mango and avocado shelf-life as well as adding value to the products. Several Kenyan players (e.g. Makueni county fruit processors Coop) indicated the need for extra processing lines to increase capacity during the high supply peaks, and to meet the increasing market demand for processed fruit.

Processing fruit does not necessarily reduce food loss. In case of oversupply when mangos or avocados cannot be sold, processing is likely to lead to fewer fruits rotting. Having said that, the processing industry, especially for an export market does usually demand high quality inputs. This means it is hard to say how much fruit waste is reduced because of processing. Processing waste into usable food or feed has become even more relevant with the new National Sustainable Waste Management Policy which obliges Kenyan businesses to process their waste sustainably[49]. Although indicative of the direction the government is taking and its priorities regarding waste management, the policy is (at present) still only on paper.

5.4.1 Avocado

There are several possibilities for processing avocado such as juice (pulp or concentrate), oil, dried products, chips, guacamole. Estimates of the degree of avocados being processed vary greatly ranging from 5 percent to even 50 percent of all avocados. "Price points of [value-added] products is 10-20 KSH for oil extraction which covers more than 50 percent of the total fruits harvested", as estimated by a farmer and Union member in Murang'a. The most common processing methods are extracting oil, and drying. Avocado waste can be used as animal feed in its direct form. Avocado waste can also be upcycled into high-quality animal feed by producing black soldier flies, a protein-rich ingredient that can be utilized as animal feed.

Olivado[50] is an example of a company processing avocados into oil. Founded in 2017 in Central Kenya, the factory packs fresh avocados for export to Europe and produces avocado oil purchased from 2,000 (mostly female) smallholder farmers. Olivado claims to produce 90 percent of the world's

[47] National Energy Grid of Kenya - National Electricity Transmission Grid of Kenya - Global Energy Network Institute - GENI conducts research and education on: renewable energy resources interconnections globally, world peace, stable sustainable development solutions

[48] Apeel reduces food loss in retail by 50%. Food loss in North America is estimated at 5% for fresh fruits and vegetables

[49] http://www.environment.go.ke/wp-content/uploads/2019/01/Waste-Policy-DISCUSSION-DRAFT-10-2-18.pdf

[50] The Story of Olivado and Our Global Success

organic extra virgin avocado oil. Olivado uses by-products to run a biogas energy plant, producing 3,000 MT of fertilizer (timeframe not disclosed). The facility contracts farmers and pays in advance which is an important factor in increasing farmer income and security. The estimates for investment depend on the region and scale. A farmer and official of the union in Murang'a estimate the costs of an avocado oil processing facility at roughly EUR 1 million:

- Extracting oil machinery – 20 to 30 million KSH (estimated production capacity >20 MT/day).
- Packhouse equipment – 60 million KSH (estimated packaging capacity >100 MT/day).
- Buildings – 45 million KSH.
- Land – 5 million KSH.

Table 14 *Estimated operational models for drying, extracting oil, and using avocado for insect feed*

	Drying	Extracting oil	Animal feed (insect)*
Description	Making healthy snacks by drying 'waste' products at 40 degrees Celsius. The shelf-life of the final product is 2 years	Extracting oil machinery to produce (cold-pressed extra virgin) avocado oil	Feeding insects on avocado and mango waste to use as an animal feed supplement for cattle and fish.
Volumes	4 MT/day	Estimated production capacity >20 MT/day	30 MT/day
End-market	Domestic market	Export market (domestic also possible)	Regional/domestic animal feed market
Location	Usually Nairobi, close to the exporters so their 'waste' can be reused	Near large-scale producers or colleting produce from several smallholder farmers	Usually Nairobi**, close to the exporters so their 'waste' can be reused
Operational model	Buying the rejected products from exporters, processing, selling to domestic market	Olivado works with certified farmers, with the products checked by hand for ripeness and imperfections. Oil is processed at less than 40 degrees Celsius to preserve nutrients	The company collects organic waste from farmers or processors in the region and uses this to feed black soldier flies (BSF). The flies are used as a supplement for animal feed, the excrements of the maggots is used as fertilizer for crops
Ownership	Investors or a group of farmers. NatureLock is an SME, founded by Dutch and Kenyan partners	Investors or a group of farmers. Olivado is an SME, originally from New Zealand, working with a general manager in Kenya	Investors or a group of farmers. InsectiPro is an SME with 64 employees.
Investment (EUR)	Unknown	Extracting oil machinery – KSH 20 to 30 million – EUR 157,000 to 228,202 (estimation by Murang'a union, not Olivado)	Unknown
Example	NatureLock	Olivado	InsectiPro
Success factors of the examples	Retains nutrients, reusing waste, affordable price for Kenyan consumer. NB: at present, NatureLock does not use avocados, but this could be an option in the future	Healthy, tasty oil. Olivado uses a biogas digestor, breaking down the organic waste from the avocado oil process and creating gas to power the generators. Olivado has fixed price agreements with farmers to reduce their risks and uncertainty and increase their profitability.	Creates valuable product from waste, reuses all parts of the products, reuses its own waste, makes the production of cattle and fish cheaper in Kenya
Picture (example)			

*Also relevant for mango

**The Kenyan capital Nairobi produces 2,500 tonnes of waste a day

5.4.2 Mango

There are several processing possibilities including mango juice (pulp or concentrate), dried products, chips, chutney, and candy bars. Several innovative options include processing the refuse into flour and other products, including leather. Mango kernels can be used for gluten-free flour, used to bake vitamin-rich cookies, energy bars and bread. Lower quality kernels can also be used for animal feed or soil conditioners (a product added to soil to improve its qualities)[51]. The degree of production innovation in the mango sector in Kenya has not yet matched the potential demand of domestic consumers. Some innovative products such as mango-based ketchup have created new demand among Kenyans. *"In our processing plant alone there is a need for more diversification of products. We need ways to ensure that all mangoes are utilized and that we can have mangoes even in off-seasons", Najyebu Ciio.*

Drying mango is an important economic activity with a export market. For producers to sell dried fruits commercially for export, they are required to possess certifications showing the fruits are produced in safe and hygienic conditions. Under these conditions, realizing the potential profitability of selling in the export market as a new entrant into the mango drying business is challenging; particularly for small scale so-called cottage industries. Nevertheless, some successful processors have emerged[52]. The opportunity of drying mangos to reduce food loss and possibly generate additional economic gains for both farmers and processors has not been fully leveraged, given the (expected) unfulfilled demand for dried fruits.

Table 15 *Estimated operational models for facilities for juicing and drying mango*

	Juice (mango pulp)	**Drying**
Description	Processing mangos into mango pulp or juice	Processing fruit through dehydration leads to a dried mango snack which can be preserved for up to 2 years
Volumes	12,000 MT pulp/year or 1.5MT mangos/hour	Estimated at >20 MT/day
End-market	Pulp is usually exported to countries in the region	Domestic market
Location	E.g., a 200-acre parcel of land, close to producers	Close to producers
Operational model	Process the mangos rejected for export	Process the mangos delivered by farmers, traders or export rejects
Ownership	Usually from investors or large farmer cooperatives	Usually an investor, company or group of farmers
Investment (EUR)	Estimated at 10.9 million KSH (~EUR 85,400) by Makueni county fruit processors Coop. "The operational costs are the cost of running the technology (e.g., fueling the trucks used), the money used to pay the technical people (drivers, technology specialists)"	Unknown
Example (company)	Galole Multi-Purpose Fruit Processing Plant	Sweetunda
Success factors of the examples		Combined with farmer training (practices, pest management) to increase crop yield
Picture (example)		

[51] generatePDF.aspx (autm.net)

[52] Azuri Health (https://www.azurihealth.co.ke/) produces and distributes naturally dried products from its processing facilities. Apart from drying mangoes, the company produces other dried fruit snacks (pineapples, bananas, coconuts and pawpaw), nutria-porridge flour and sweet potato flour. The company sells locally, but is increasingly targeting the export market

Mango can be dried through various technologies, including freeze-drying and solar drying. The freeze-drying avocado and mango creates a snack with a long shelf life and conservation of nutrients. Examples of this are Sweetunda[53] and Nature Lock[54] (formally Fibered Fresh Partners).

5.4.3 Feasibility and sustainability

There are several considerations and critical conditions for investment:

- Processing facilities are highly dependent on the supply of products. Mango and avocado are both seasonal products with a harvest period of about four months. During this time there will be an oversupply, whereas the supply of these products will be low in the non-harvest months. A possible contribution to solving this is to increase the number of (temperature-controlled) storage facilities throughout the country, so the product can remain fresh for a longer period and increase the access time for processing facilities to the produce;
- Besides seasonal differences, there is a major difference in the yield between years;
- The harvesting conditions and product quality upon entering the facility is an important consideration (variety, ripeness, temperature, the time before entering storage or packaging); and
- Usually, processing solutions require large volumes to be profitable.

Processing solutions greatly contribute to sustainability by using products of lower quality or inedible parts of products. At present, the waste of mangos and avocados is usually fed to animals or thrown away.

5.4.4 Potential food loss reduction

Processing products has many advantages including the use of products otherwise lost (lower-quality products), turning inedible parts of products into edible products, and value-addition. Although difficult to estimate, the reduction is estimated at 10 percent of edible products. The use of inedible products depends on the processing method and waste management.

5.5 Industrial slaughtering of poultry

Based on Dutch standards only very few players in the poultry sector in Kenya qualify as large-scale, most notably Kenchic is one of these companies. There is potential for increasing production of hygienically and industrially slaughtered poultry, especially for a high-class segment of large urban supermarkets, up-market hotels and international franchises (such as KFC). This can be achieved either through large-scale slaughtering and processing facilities or potentially through (mobile) small-scale slaughtering facilities. Aggregating the produce from several farmers could be an opportunity to introduce hygienic slaughtering to smaller-scale farmers.

Critical investment conditions include:

- High input of primary products and demand for value-added poultry products;
- Concentrated and organized markets (with regulations on food safety, traceability in place);
- Improved transportation of live birds, cold chain storage capacity, water purification, electricity, and waste management.

As summarized in table 16, for a slaughter facility (13,000 chickens/hour), partly automated and partly with manual labor, processing whole chickens, with a small cooling facility and low-end packaging, investments are estimated at EUR 1,3-1,8 million. For small (mobile) slaughtering facilities (<1,000 birds per hour, sometimes as small as 500 birds per day), installation costs are estimated at EUR 300-350,000. However, even the large-scale slaughtering facilities in Kenya (Kenchic, QMP, and Kims poultry) are currently not operating at full capacity making the mobile slaughterhouses currently an unrealistic alternative.

[53] https://sweetunda.com/.
[54] naturelock.co.ke)

Table 16 *Estimated operational models for small to medium, and large-scale slaughtering facilities*

	Small-medium scale slaughtering facilities	Large-scale (Kenyan standards) slaughtering facilities
Description	Small, mobile slaughtering facility.	Slaughter facility partly automated and partly with manual labour, processing whole chickens, with a small cooling facility and low-end packaging
Volumes	500-1,000 chickens/hour	13,000 chickens/hour
End-market	Domestic market (e.g. restaurants, urban population, supermarkets)	Domestic and regional market (e.g. KFCs in Kenya, Rwanda, Tanzania).
Location	Near producers	At the large-scale (integrated) producers
Operational model	• Collection live bird from a farm – 2 KSH • Electricity – 7 KSH/ bird • Water – 2 KSH/bird • Labour – 3 KSH/bird • Factory operation cost total 10 KSH /bird	The Kenyan buyer would purchase the facility from the supplier, who would be responsible for construction and support. After construction, the lines usually do not require updating for 10 years. During that time, the buyer would be responsible for maintenance.
Ownership	Group of farmers or association, investors	Kenchic, other large-scale companies, or (DFI) investors
Investment (EUR)	300-350,000	1.3-1.8 MN
Example (company)	N/A	Kenchic, Marel, LINCO, Foodmate, Meyn
Picture (example)	N/A	

Dutch players (Marel, Meyn, LINCO) consider Kenya to be a small market. Larger Kenyan poultry slaughtering companies include Kenchic, QMP, and Kims poultry. ColdSolutions estimates the formal poultry market to account for around 20 percent of the total market (the other 80 percent is informal, mostly at wet markets).

5.5.1 Potential food loss reduction

There are relatively few losses in the large scale, industrial poultry slaughtering sector. Potential food loss reduction is estimated at 1-10 percent when slaughtering and processing facilities are upgraded to higher standards. Equally important, the product quality would greatly increase, as well as hygiene and food safety.

5.6 Rendering poultry "waste" into high-quality proteins

A promising solution to use the "waste" of poultry is rendering the feathers, blood, and intestines into high-protein flours and oils. These are valuable products for animal feed, thereby increasing circularity and more sustainable livestock production. Processing waste into usable food or feed has become even more relevant with the new National Sustainable Waste Management Policy, which obliges Kenyan businesses to process their waste sustainably. Although indicative of the direction the government is taking and its priorities regarding waste management, the policy is (at present) still only on paper.

About 30 percent of the bird (blood, feathers, carcass) is not eaten by humans and can be used to make the following final products, available to the regional East African animal feed market or export:

1. Feather flour: dog feed, 70-90 percent protein. Price: EUR 700 / MT. An integrated poultry player (e.g. Kenchic) could add this to their animal feed production line;
2. Blood meal: sells for EUR 1,000 / MT, with 90-92 percent protein content; and
3. Oils: used as a flavor enhancer for animal feed or as gasoline.

Critical conditions for investments include:

1. High input and demand are required to be cost-effective. To be relevant for Dutch suppliers, the threshold would most likely lie at more than 15 MT of waste per day. Production of 1,000 chickens (each weighing 2 kg) slaughtered per hour for 12 hours per day leads to 3 MT feathers/day. Notably, a rendering facility does not only work for poultry meat. It can process the waste of pigs, livestock and even fish as well.
2. Requires concentrated, organized markets (regulations to be in place).
3. Products need to be transported to this main facility in refrigerated trucks, or in less than eight hours after slaughtering to prevent decay.

The investment costs for a rendering plant range depending on the size and location of the plant. A small rendering plant, suitable for the Kenyan context, would likely cost somewhere around EUR 400,000. Variable costs include labor, energy and steam, with labor costs in Kenya varying from EUR 5-40/day. According to Mavitec there are few risks for a Kenyan buyer as on-site support is given during the construction of the facility. For the first 2-3 months, the Mavitec staff would be there for construction and to train the local staff. For the next 2-3 months, the staff is available for aftercare and to ensure the local staff can run the facility. After installation support is given remotely. For more details, see table 17.

1. Complete plant: 100 MT/day. Investment costs are estimated at EUR 8 to 10 MN.
2. Two containers for small quantities: 5-15 MT/day. EUR 300-400,000. The facility can use products from a cluster of small slaughterhouses.

Table 17 *Overview of potentiality of rendering facilities at different scales*

	Medium-scale rendering facility	Industrial-scale rendering facility
Description	Two containers for small quantities	Complete plant
Volumes	5 to 15 MT/day	100 MT/day
End-market	Local or national feed market	National or East-African feed market
Location	Close to producers (collect material from a cluster of small slaughterhouses)	At a large-scale, industrial slaughtering facility (e.g. Kenchic)
Operational model	Producers deliver their waste for a fixed price, the input is rendered into high-quality products at the facility. This must happen cooled and in less than eight hours to prevent decay.	Large-scale rendering facilities are usually installed at or close to the slaughtering facilities. The transport of the waste to the rendering facility covers a minimal distance and there is no chance of spoilage. The output of the rendering facility can then be used as an input for the feed milling facility.
Ownership	Either a group of farmers or an investor	Industrial slaughter facility (e.g. Kenchic)
Investment (EUR)	300-400,000	8-10 million
Example (company)	Unknown	Mavitec (NL),
Success factors of the examples	Accessible to small-scale farmers, catering for the domestic market for increased circularity.	Efficient. Providing valuable proteins as a high-end supplement to animal feed. This can replace less sustainable alternatives such as soy which is not grown in the East African region and thus needs to be imported.
Picture (example)	N/A	

5.6.1 Potential food loss reduction

The proposed intervention does not contribute to a direct food loss reduction but over 30 percent of the live weight is used, contributing increased circularity in the poultry sector.

6 Conclusions and recommendations

This study aims to make the food system in Kenya more sustainable and resilient by focusing on one particular aspect of the Kenyan food system: food processing and agri-logistics related to food losses and waste. An assessment of this part of the food system assists to identify food loss hotspots and sustainable solutions to reduce those losses. The study was guided by three questions:

1. What are the post-harvest losses in the food system, specifically the mango, avocado and poultry value chains of Kenya, and what options are available make the food system more efficient?;
2. What is the scope for innovation, knowledge and appropriate technologies in processing and agri-logistics that help in reducing post-harvest losses?; and
3. Are there opportunities for (Dutch) investors and entrepreneurs to contribute to a more sustainable food system in Kenya?

6.1 Conclusions

We would like to present the following conclusions:

1. There is a substantial difference in post-harvest losses between the large scale commercial (export) sector in the three researched value chains and the small scale predominantly domestic market sector. Food losses in the large scale (export) sector vary between "limited" in the industrial poultry slaughtering industry and 15 percent in the avocado export sector; losses in the mango and avocado value chains targeting the domestic market reach beyond 35 percent (and this is considered a very conservative estimate).
2. Not surprising, with the exception of poultry where one big player supplies the domestic market with processed chicken, the domestic market is generally supplied by small to medium scale companies, and the export market generally by bigger companies who can afford to meet export standards, and thereby minimise losses.
3. In all three value chains, in terms of volumes, the domestic market is much bigger than the export market (roughly 3:1 for all three value chains). This means that the potential gains in reducing post-harvest losses is much higher with a focus on the domestic market rather than the export market.
4. The solutions that are available for reducing post-harvest losses are many, and they are often inter-related. In the report a distinction is made between "*desired integrated interventions*" and "*business opportunities*". The former refers to a host of elements of recommended sector improvement: training of farmers, traders, and vendors as key actors with the potential to reduce losses significantly (in Good Agricultural Practice, product handling, Integrated Pest Management), sector coordination (available market information, formal contracts, market linkages), an enabling policy environment (incentives, regulations), stronger producer organizations, improved access to finance, and improved infrastructure, as well as a system of traceability, quality assurance and food safety. The argument is that introducing a technical innovation in a sector that is flawed with inefficiencies is likely to fail. The study concludes that productivity (in all three chains), market development and the regulatory environment needs to be improved for losses to be reduced and the food system to operate more effectively. An assessment of the potential loss reduction as a result of "*desired integrated interventions*" was impossible to provide.
5. The study identified six *business opportunities*. For the avocado/mango chains: investments in temperature-controlled storage, aggregation facilities, packaging solutions and processing technologies. For poultry: industrial slaughtering facilities and rendering facilities.
6. The six business opportunities promise reduction of post-harvest losses. In the mango/avocado chain it is estimated that post-harvest losses can be reduced by 30-60 percent by investing in temperature controlled storage. When aggregation facilities and related agri-logistics systems are in place and efficiently managed a maximum of 20 percent loss can be reduced. With effective packing solutions and shelf-life extension techniques along the chain yet another 30-40 percent losses can be reduced. Post-harvest value addition and processing can reduce a maximum of 10 percent of the total losses by using low-quality fruits that otherwise would be lost.

7. The poultry sector paints a different picture: the potential reduction of losses in the industrial slaughtering and processing sector is limited as the industrial poultry sector in Kenya is well-organised. Reduction of losses can be gained especially in the small-scale poultry sector supplying live chickens to wet markets (meeting 70-80 percent of the poultry consumption in Kenya). In that domain much can be gained not so much by technologies but more by improving business practices and enforcing animal welfare and public health regulations towards better transport of live chickens, higher hygiene standards, biosecurity and food safety. 30 percent of the chicken carcass (feather, intestines, etc.) is not consumed and considered waste. Rendering technology can turn that waste into useful products such as animal feed. In doing so, approximately 30 percent of food loss could be turned into useful products that contribute to a circular economy.
8. Are there opportunities for (Dutch) investors to help in reducing post-harvest losses? This question is not easy to answer. As mentioned above, the losses are highest in the domestic market sector dominated by small-scale farmers and cottage industries. This is not the typical environment in which the predominantly sophisticated large-scale Dutch companies operate. The average Dutch industrial poultry processing line is five times bigger than the biggest Kenyan processor. Dutch investment in rendering facilities in Kenya offer more prospect. Necessary investments in the small-scale poultry (transport) market are not likely to draw Dutch interest. Roughly the same applies to the mango and avocado value chains. The domestic markets are bigger then the export markets and post-harvest losses are bigger but operations are small scale. These scales of operation are not the ones in which one can fit large scale cold storage solutions, sophisticated aggregation and packaging solutions, and industrial processing. There seems to be a mismatch between what the Netherlands competitively offers and what small farmers need to reduce the substantial post-harvest losses. If sector wide interventions could count on additional development funding effective business cases to reduce food loss can be developed.
9. One can conclude that Dutch solutions in storage, aggregation, packaging and processing can be very valuable in the Kenya avocado and mango sectors but especially related to export as that sector better fits the scale and investment power of Dutch companies and service providers. In that case the purpose in not so much to reduce post-harvest losses (which are low already) but to tap the growth potential of both sectors that is promising to be substantial.
10. For the domestic market sector the most promising technology that can substantially reduce post-harvest losses in mango and avocado is in the cold storage chain, preferably in an integrated form including very small, low-cost, appropriate technology solutions such as on-farm charcoal evaporative coolers; medium-scale cold storage container solutions at local aggregations localities; and large scale cold stores at urban markets (with refrigerated transport in between). Especially the medium scale cold storage container is regarded as feasible and effective investment to bring down food losses. This technology is readily available in Kenya either as product from the shelf, or as part of a service agreement in which the user pays per kg of storage, and management is done by the owner company.
11. A cost-benefit assessment of such technology showed profitability for both mango and avocado assuming a loss reduction of 5 percent (reducing losses from 35 percent to 30 percent in the avocado chain). In addition, a climate impact assessment showed that total emission reduction effect (= the CO2 emission caused by the post-harvest losses) is significantly higher than the extra emission induced by installing and powering the technology.
12. Aggregation logistics solutions, packaging and coatings in both the mango and avocado sector are relevant technological solutions to reduce post-harvest losses but seem currently more appropriate for the export sector, in particular when considering sea freight transport.
13. The mango and avocado processing industry in Kenya is also largely targeting export. With export markets such as China expected to grow there is potential for investments in especially medium to large scale companies (that can meet export standards).

6.2 Recommendations

1. The export market of Kenya for mango and avocado, either fresh or processed is expected to grow substantially in the years to come. Both for mango and avocado there is currently a large unfulfilled demand. For mango the export market is expected to increase largely due to the expected increased accessibility of the lucrative European market. The avocado market is also

continuously growing with the Chinese market demand only 70 percent fulfilled, offering solid potential. The CEO of Kenya's Directorate of Horticulture announced plans to prioritize avocado export to China[55]. Dutch investors, and input suppliers will be able to match their investment ambitions by establishing partnerships with large-scale farmers, traders and processing corporations in the export sector. The domestic market is more likely to benefit from smaller and/or social investments as well as knowledge and good practices as provided by development partners and knowledge institutes.

2. With production of avocados and mangos expected to increase, the need for professional and efficient production, storage, transport, packaging, and processing increases. Although Dutch technology is often more expensive than Chinese and Indian technology (up to three times), the Dutch private sector can assist Kenyan players and enter this emerging region by partnering with financial institutions and with support from the Dutch government (see also 'Utilization of available funding instruments').
3. There is a promising market for temperature-controlled storage and cold chain solutions with large-scale solutions being most relevant for Dutch suppliers. With Kenya's plan to increase export to the Chinese market, temperature-controlled storage and cold chain infrastructure become even more important as avocados are shipped frozen to the Chinese market. This offers increased opportunities for value addition on Kenyan soil. Investments range from EUR 22,000 (including taxes and import) for a solar-powered, mobile container up to EUR 60 million for an industrial-sized, multi-purpose warehouse.
4. Relevant Dutch companies are recommended to explore the Kenyan mango and avocado export market for supply of aggregation and packaging solutions to streamline production processes and increase the competitive edge of the country.
5. The same applies to potential partnerships with Kenyan private sector corporations producing juices, pulp, and avocado oil, as they see a largely unfulfilled market. Also in this case the market focus will be mainly export.
6. For the domestic market of mango and avocado the investment conditions will be different. While post-harvest losses can be reduced by up to 50 percent a much more integrated sector approach is required to make that happen. This includes the collaboration of private and public partners to jointly build a conducive environment for private sector investments across the entire value chain. Such PPPs would be relevant and potentially economically viable initiatives in either the mango or avocado chain. Such initiatives could include groups of farmers improving the yield and quality of production, a transport and trade segment with improved market information system, a commercially-run processing facility, an integrated cold storage chain at the different levels of production including refrigerated transport, all input suppliers from nurseries to packaging, and agri-finance institutions. The Embassy is recommended to explore such PPP arrangements, for example for avocados in Murang'a county; or for mangos in Makueni.
7. In the poultry sector relevant companies are recommended to explore investment and/or provide services in rendering facilities to process poultry slaughter waste into high-end animal feed supplements. These products can be sold on the national or regional East African animal feed market. A complete rendering plant, processing 100 MT of poultry waste per day, requires an investment of EUR 8-10 million. Smaller-scale facilities (two containers for quantities of 5-15MT/day) require an investment of EUR 300-400,000.
8. For the domestic market, necessary developmental interventions are recommended to improve the transport of live birds and improved biosecurity through veterinary checks.
9. Effective and sustainable post-harvest loss reduction requires sector wide, bundled approaches that focus on multiple and interacting components and are customized to particular context (supply chain, geography, stakeholders, target market, etc.). Two core preconditions for success are horizontal integration of farmers' into organizations and aggregated groups and vertical integration of supply chain stakeholders.

[55] Kenya seeks to boost avocado exports to China - Chinadaily.com.cn

6.3 Place-based interventions

Business opportunities need to be tailored to the specific regions and Kenyan Counties as there are huge regional differences. Drivers and causes of post-harvest losses differ amongst these Counties. Customized place-based intervention strategies that are based on the field realities of each area will generate most impact.

6.3.1 Avocado

The key counties for avocado production in Kenya are Murang'a, Kisii, Nyeri, Nyamira, Meru and Kiambu:

1. Cold storage and aggregation facilities, proper packaging and processing would provide great benefits for the avocado sector in Murang'a due to its distance to the end market.
2. Murang'a produces significantly more avocados than Kiambu and the other central Kenya counties. Losses are higher and therefore potential loss-reduction is higher.
3. Murang'a has more organized farmer groups than other counties and therefore it would be easier to set up aggregation centers.
4. For Kisii and Nyamira, packaging and local transport must be improved as it is the main cause of post-harvest losses. The majority of producers pile avocados into pick-up trucks in large sacks leading to the loss of significant quantities.
5. Kisii County is currently planning to increase the production of high-end avocado oil through investment in an oil extraction plant. The county also supplies seedlings to farmers to improve the quality and grow avocados with high oil content.
6. All counties stand to benefit from improvement in cold storage solutions at appropriate scale.

6.3.2 Mango

Cold storage and aggregation centres are needed across all regions (Makueni, Machakos, Murang'a, Embu and Nairobi) albeit at different scales.

Makueni already has a fruit processing plant (Kalamba Fruit Processing) whereas Machakos and Embu only have small-scale aggregation centres (in Masii and Karurumo, respectively). Makueni would greatly benefit from a large-scale aggregation centre with an affordable/sustainable cold storage facility and training of farmers so the percentages of mangoes rejected at the processing plant due to quality issues can be reduced. Up-scaling is needed for the aggregation centres in Machakos and Embu with the possibility of setting up new ones. The 4-5 tonnes of mangoes that the facilities can each carry is far below the production potential of the regions.

In Embu County, a vast number of smallholder producers has access to irrigation for the production of mango of the Kent variety, highly demanded in the export market.

6.4 Utilization of available funding instruments

Financing is often a major issue for Kenyan companies when considering investing in Dutch technology. Although Chinese and Indian technology is significantly cheaper (sometimes a third of the Dutch price) it is often not of the same technologically advanced level. Furthermore, multiple interviewees have indicated difficulties with a lack of service and manuals provided by Chinese suppliers. With financing opportunities, Kenyan companies can invest in high-end Dutch technology whereby Dutch companies can offer long-term support, service and after-care upon finding the most suitable solution.

Dutch private sector companies can make use of several support opportunities provided by the Dutch government. This can include credit, subsidy, or making use of the existing network of the Dutch government. Furthermore, export insurance companies offer insurance and credits for suppliers and buyers. Useful websites with further information include:

- Doing business | netherlandsworldwide.nl
- Home | DGGF
- Funding | RVO.nl
- Facility for Sustainable Entrepreneurship and Food Security - FDOV | RVO.nl
- DHI subsidy scheme | RVO.nl
- Atradius Nederland | Kredietverzekering en incasso

Many Kenyan companies struggle with acquiring finance to make capital investments. Companies such as Atradius offer cheaper financing than Kenyan banks. A normal loan from a Kenyan bank to cover product financing would be against a 16-20 percent interest rate whereas Atradius offers much lower rates (approximately 5 percent), provided that the Kenyan company is large enough and reliable. The Kenyan player must commit to the loan by covering 20 percent of the costs themselves, where Atradius insures the remaining 80 percent. The cheaper financing opportunity makes Dutch suppliers more attractive.

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Appendix 1 Scope and methodological approach of this food system study

Scope of the study

In consultation with the Netherlands Embassy in Nairobi a choice was made to focus on three value chains: mango, avocado and chicken. The rational of this choice:

- Priority value chains in National policies and county level strategies
- Value chains that are relevant for export and domestic markets
- Value chains that are representative for nutrition dense, perishable food products
- Value chains and topics that are aligned with the Multiannual Country Strategy established between the Embassy of the Netherlands and the Government of Kenya.

Geographically the decision was made to zoom in on three counties to study the mango supply chain: Makueni, Machakos and Embu. The underlying rationale for selecting these counties is based on the fact that they are counties who have prioritized the mango sector in their development strategy and supply large volumes of Mangoes both for the domestic as the export market.

For the case of the avocado supply chain Muranga, Meru and Kisii were selected as focus counties. These counties are representative of the avocado supply system in Kenya and, are counties that produce vast volumes of Avocado. In these counties the Avocado supply chain has been prioritized as key agricultural development sectors.

Three counties were selected to zoom in on the poultry sector. These counties, Nakuru, Makueni and Thika are strong poultry producing counties, have commercial ties with urban markets and are counties where the poultry supply chain has been identified as key priority for agricultural development.

Approach and methodology

Guided by the food system framework developed by van Berkum, *et al.*, (2018) – see figure 1- and the food systems decision support toolbox developed by Posthumus *et al* (2021), a customized approach was designed for the purpose of this assignment that takes on a food system approach to look at post-harvest losses within three particular value chains in Kenya.

Customized approach – use of the food system analysis methodology

Using such an integrated food system approach to study post-harvest losses, will provide insights in how unsustainable food systems contribute to food losses and how the reduction of food losses could improve the sustainability of food systems. This analysis will focus on food processing and agrologistics as a core activities within the food system.

Food system approaches take an integrated approach, looking beyond the food value chain in order to include environmental and socio-economic components and food security outcomes. This perspective is considered as a useful framework for understanding changes and for shaping transformative action at the interface of science and policy.

Taking a food systems perspective the analysis will highlight how each of the elements within a food system interacts with other food system elements in generating food system outcomes. Figure 1

shows how a focus on food storage, transport and trade and food processing and transformation could eventually lead to broader food system outcomes.

The methodological approach will map out how each of the three sectors is affected by socio-economic and environmental drivers. In addition it will look into the food system activities to analyse the behaviour and interaction of food system stakeholders and to assess how these characteristics affect post-harvest losses.

Based on a combination of literature review and, interviews with stakeholders and experts post-harvest loss profiles will be set up that identify the specific stages in the food supply system where post-harvest losses occur. By analysing these critical loss points the study will unravel how post-harvest losses at different stages of the food supply system affect stakeholders and ultimately the food system outcomes.

In the formulation of leverage points and recommendations a number of core post-harvest management and food system objectives were considered based on the work of Verschoor *et a*l (2020). These underlying objectives are:
Leverage points must have the ability to:

- Improve food availability in quantities by minimizing post-harvest losses
- Improve food availability by increasing the shelf life and amount of time that a food product is available
- Improve food availability in different regions by enhancing the ability to transport fresh and perishable foods to distant markets.
- Improve food affordability through price stabilization
- Improve income of supply chain actors
- Improve food safety
- Improve nutrition and food security by enhancing access, affordability and availability of nutrition dense, fresh foods to complement diets
- Reduce impact on the environment by reducing post-harvest losses and related resource use inefficiencies and additionally considering leverage points that do not have a strong environmental footprint.

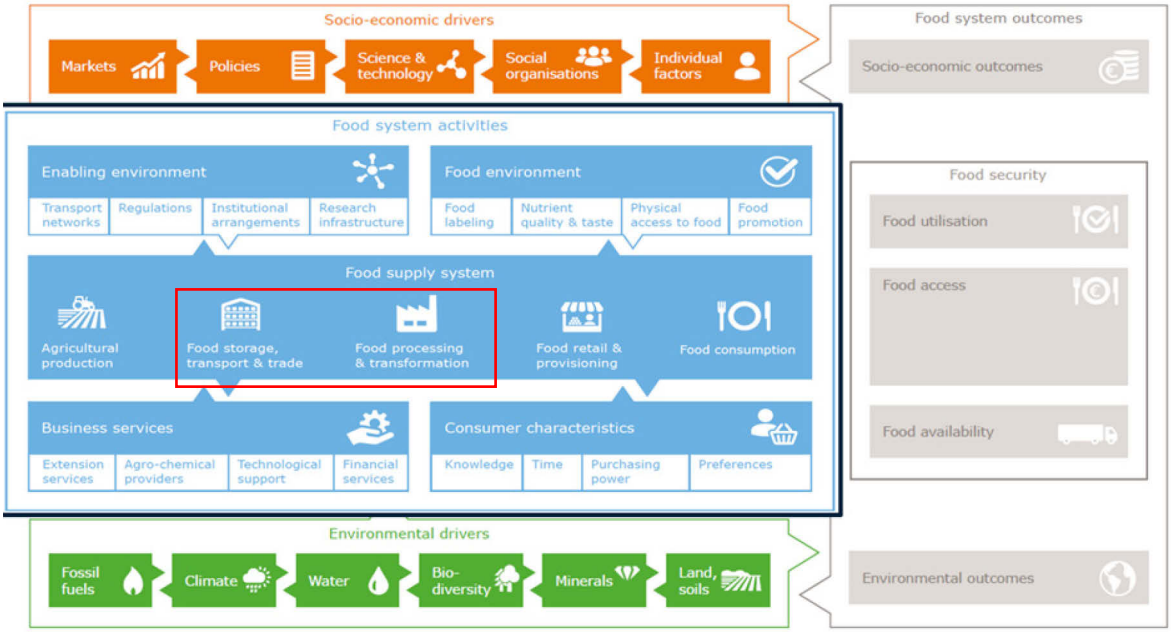

Figure 10 *The Van Berkum et al. (2018) conceptual food systems model*

By highlighting the various vulnerabilities related to food processing and agrologistics, this assessment looks at the factors that affect post-harvest losses and defines recommendations on elements that

should be addressed to reduce and mitigate post-harvest losses through food processing and agrologistics. The analysis provides insights in how tackling these factors will contribute to the sustainability, inclusiveness and resilience of the food system in the long term.

Data collection methods

Rather than engaging in direct measurements of post-harvest loss in the field, this study looks at post-harvest losses through existing information and data, combined with stakeholder and expert insights. This resulted in the creation of 'conservative estimates' of post-harvest loss and loss profiles that have been identified, verified and validated by key stakeholders in the respective Kenyan food systems[56].

For each of the three value chains, a large number of stakeholders have been interviewed and approached. Stakeholders were carefully identified in order to ensure their representativeness and knowledge of the particular value chains in question.

- Stakeholders directly involved in the production activities (farmers, farmers organizations, sector level associations)
- Stakeholders involved in agroprocessing and agrologistics (private companies, marketing agents, exporters, NGOs, etc.)
- Stakeholders involved in research activities (Universities, national research organizations, consultants)
- Stakeholders supporting and regulating (Government officials, public regulating organizations, county-level authorities

The results of this research are based on the cumulative and combined findings from different research methods. The desk research has offered great insights into the supply chains and food loss of avocado, mango, and poultry. These insights have been used as input for questionnaires and interviews with various private sector players in the Netherlands and Kenya.

By validating the research findings and filling the knowledge gaps, 'triangulation' (the combination of desk research and primary interviews, self-reporting, expert opinions), has led to a more complete overview of the organization of the food system supply chains, the business practices contributing to post-harvest losses, and the desired interventions and opportunities to reduce food loss.

Based on the information obtained an estimation of the food loss profiles for each food product has been developed. Considering that food loss profiles are prone to variation and are affected by seasonal and regional variations and specific farm-level practices the calculations for this assessment are based on conservative weighted averages.

Research assumptions

Several assumptions were made, including:

1. By using triangulation and interviewing experts of different parts of the supply chain in each sector, the resulting post-harvest loss profiles are the best estimate. There is limited reliable data and information (freely) available and estimates vary between years, seasons, regions and farmers. It is assumed that the interviews represent the sectors in the different counties.
2. The estimates of post-harvest losses are conservative.
3. It is assumed that all interviewees have answered the questions honestly and to their best ability, which is guaranteed by anonymity and best-effort estimates.
    a. Anonymity: To guarantee truthfulness, all participants in the research were informed in advance that their name, designation and company would remain anonymous to the external report, should they prefer this. They were made aware of the fact that the writers of the report (Wageningen University and Larive) and the Embassy would be able to see their names. Also, the interviewees that were recorded were asked for permission in advance.

[56] Three stakeholder validation workshops were organized to present, discuss and validate the findings from this report with key stakeholders representing the three different value chains that this study looked at

b. Best-effort estimates aim: many interviewees indicated to be unable to answer several questions regarding food loss estimates or most promising business opportunities, as the situation on the ground is complex and diverse. Interviewees were assured their best-effort estimates were valuable to the report.
c. No sensitive information: respondents were not asked about information that would be considered too sensitive, culturally inappropriate or even rude, such as company balances, exact profit margins, personal incomes, and religious practices (relevant for poultry consumption).

Research limitations
The major limiting factor to the research was the rather closed attitude of several private sector players. The major reasons for this included fear of competition and a lack of overview of the sector. Many companies are hesitant to share valuable and sensitive information, as they are at risk of making their company more vulnerable to competition or to benefit competitors or new entrants in the market. The sectors (avocado, poultry, and mango) are complex, unstructured, and highly diverse across regions, years, and farmers, which means many interviewees did not feel capable of giving an accurate overview of the sector.

Figure two provides an overview of the main research limitations encountered in private sector interview that were part of this assignment.

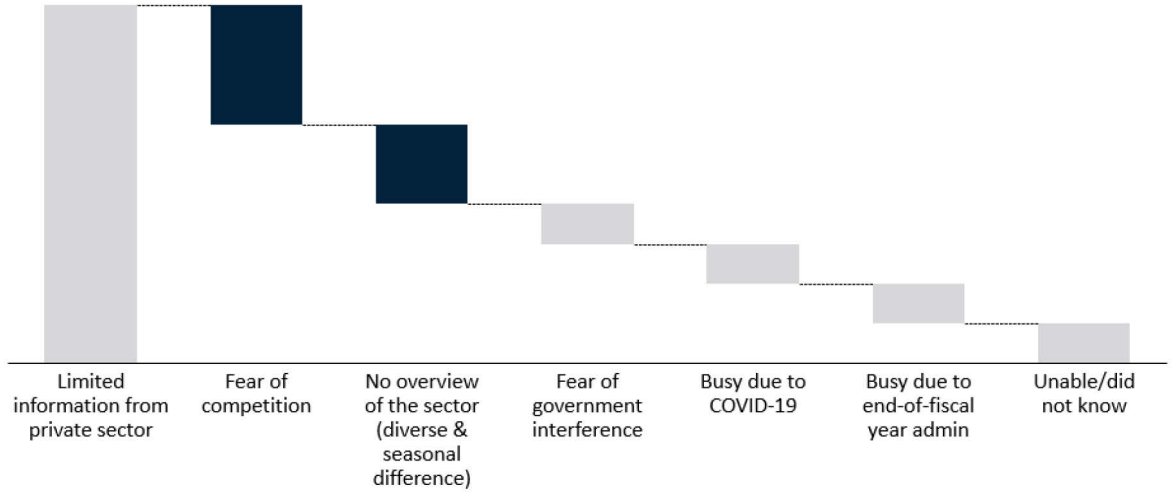

Figure 11 *Research limitations during private sector interviews (mostly with Kenyan players), with the dark blue colours indicating the main obstacles for private sector players to participate in the research*

Team composition

A multidisciplinary team of researchers and analysts were involved in this research assignment combining a variety of disciplines and specialties relevant for this assignment. Combining food system insights with post-harvest loss expertise and business dynamics has allowed the researchers to approach the complex issue of post-harvest losses from multiple entry points.

- Herman Snel – Wageningen Centre for Development Innovation - project lead and food system analyst.
- Jan Broeze – Wageningen Food and Biobased Research – Supply chain and post-harvest loss analyst.
- Florine Kremer and Amber van Spronsen – Larive International – Business analysis.
- Julie Muyela, Emmanuel Wanjuu, and John Erick – Lattice Consulting and Lattice Aquaculture – Business analysis.
- Emily Osena – Independent Kenyan based consultant and post-harvest loss analyst.

Appendix 2 Selective stakeholder overview per sector

Avocado

Kenyan private sector (or active in Kenya)	Dutch private sector	Potential investment partners	Other stakeholders
• Olivado • Percy Oils • East African Growers • KEITT • Twiga Foods • Nature Lock • Apeel (USA company running a pilot in Kenya) • Sweetunda • Kakuzi • Sasini • Biofarms • Vegpro • Sunripe • Kandia Fresh Producers • Mt Kenya Avocado Farmers • MAVOK • OJ Green • Mofarm • Njoroge Fruits • Biofarms • Best Tropical Fruits • SokoFresh • Cold Hubs (Nigerian, interest in Kenya) • Cold Solutions • BigCold • Alpha • KALRO • DHL • Cool Link	• Omnivent • Groentenfruithuis (association) • Remmert Dekker • Jasa packaging solution • Nature's Pride • VPK Group • Aweta • Liquidseal • SokoFresh • Cool Green Solutions • Celtic Cooling • Geerlofs • Kloosterboer • Adheerest • Coolfinity • OTFLOW	• One Acre Fund • Absabank • Rockefeller Foundation • Bill & Melinda Gates Foundation • Local private investors • Hooge Raedt Social Venture (HRSV) • Rabobank • World Food Programme • UKAID (DFID) • Dutch Fund for Climate Development • World Economic Forum	• Sacco • Horticulture Development Authority • KEPHIS • Avocado Society of Kenya • Global Cold Chain Alliance (GCCA) • Cold Chain Assessment Initiative (2015), an initiative of the US and Kenyan governments (International Trade Administration at the U.S. Department of Commerce)

Mango

Kenyan private sector (or active in Kenya)	Dutch private sector	Potential investment partners	Associations and initiatives
• SokoFresh • Cold Hubs (Nigerian, interest in Kenya) • Cold Solutions • BigCold • Alpha • KALRO • DHL • Cool Link • East African Growers • Best Tropical Fruits • OJ Green • Njogore Fruits • KEITT • Twiga Foods • Makueni Fruit Processing Plant (MFPP) – capacity 5,000 kg/hour, 8 h/d à 40,000 kg/day • Coop, • Fruits company (formerly Makiyika processors), • Huruma Asili foods, • Kithoni Mango processors • Pamoja Tunda in Mbooni, • Sunny processors • Goshen ltd- Alex Muli • Huruma women group in Kibwezi (Asili foods ltd) • Vert ltd • Kelvian ltd • Premier ltd • Meshack Kioko • KEITT exporters – Japeth Mbandi • Mofarm fresh fruits exporters – Boniface Mutungi • Premier • Sonic • GMS	• SokoFresh • Cool Green Solutions • Celtic Cooling • Geerlofs • Kloosterboer • Adheerest • Coolfinity • OTFLOW	• One Acre Fund • Absabank • Rockefeller Foundation • Bill & Melinda Gates Foundation • Local private investors • Hooge Raedt Social Venture (HRSV) • Rabobank • Kigali Cooling Efficiency Program • World Food Programme • UKAID (DFID) • Dutch Fund for Climate Development • World Economic Forum • TNO	• Global Cold Chain Alliance (GCCA) • Cold Chain Assessment Initiative (2015), an initiative of the US and Kenyan governments (International Trade Administration at the U.S. Department of Commerce) • Sacco • Baseline Survey Report, Makueni County, December, 2019

Poultry

Kenyan private sector (or active in Kenya)	Dutch private sector	Potential investment partners	Other stakeholders
• Kenchic • QMP • Isignya Feed • Kenbird • Muguku Poultry Farm • Brade Gate poultry • Kukuchic • Kenya Bixa • Kims Poultry • Genesis Farms • Muguku Farm • Brade Gate • City Market • Gikomba Market • Burma Market • Kariokor Market	• Marel • Meyn • Bader LINCO • Foodmate • Mavitec	• One Acre Fund • Absabank • Rockefeller Foundation • Bill & Melinda Gates Foundation • Atradius • Local private investors	• KMFRI • KALRO • Ministry of Agriculture, • NEMA • Kenya Poultry Farmers Association (KEPOFA) • Association of Kenya Feed Manufacturers (AKEFEMA) • The Avian Influenza Preparedness National Task Force is funded by the Government of Kenya, USAID, FAO, and DFID. • National Agricultural Extension Programme (NALEP) funded by the Swedish International Development Agency (SIDA). • Strengthening of Agricultural Training Centers (ATCs), formerly the Farmers' Training Centers (FTC) funded by the Government of Kenya. • World Vision International, CARE International and Oxfam

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