Reduction of Food Waste of Avocado During Post-harvest in Kenya by Applying Technology

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Summary

Avocado is a tropical fruit with great commercial value. But there is a serious food waste problem in Kenya. This report focused on four aspects of post-harvest, namely sorting, packaging, storage, and transportation to investigate the technologies applied to reduce food waste. Therefore, this report aimed at reducing the food waste of avocados during post-harvest in Kenya by applying technology. The current statements in Kenya and technology examples were shown in results through literature studies and interviews with exporters and experts in Kenya. The difficulties in carrying out the technologies and methods to eliminate were mentioned in the discussion. This report proved that many technologies, such as non-invasive technology, Ozone treatment, pre-packaging wax, Controlled Atmosphere (CA), and Radio Frequency Identification (RFID), were suitable for Kenya. Kenya's economic situation and operational skills popularization might affect the use of technology. Therefore, it was necessary for the government to provide financial support and establish cooperatives with developed countries. According to the negative impact of avocado waste on Kenya's economic income and sustainable development, the information in the report had important implications for the further development of processes for managing post-harvest losses of avocados in Kenya.

Keywords: Kenya; Technology; Food waste; Avocado; Post-harvest

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1. Introduction

As a healthy food option, the popularity of avocado has dramatically increased in recent years, not only as a fresh product but also for various processed products. In Kenya, the Avocado commodity chain is still relatively in its infancy but has many challenges ahead for sustainable development. Too much avocado loss and waste in the supply chain are some of the most important reasons causing unsustainable development in this chain.

This food waste and loss have a profound impact on the environment, leading to negative impacts such as carbon dioxide emissions (Timmermans et al., 2014), biodiversity loss, deforestation, and waste of water and fertile soil (Gustafsson et al., 2013). To stimulate the reduction of food waste and loss, in 2015 the United Nations General Assembly adopted a target to halve food loss and waste along the food supply chain under the Sustainable Development Goals for responsible consumption and production (Griggs et al., 2014).

The project is commissioned by Woody Maijers, who is an active member of the platform (Food waste Reduction and food Quality living LAB) FORQLAB. The platform is aimed to reduce post-harvest loss and improve the efficiency of the food system in Kenya. The project is financed through SIA (the Taskforce for Applied Research SIA, or Regieorgaan SIA), the organization is aimed to improve the quality and widen the impact of the applied research that done by Dutch applied sciences universities by funding and promoting collaboration between these universities, industry and public bodies.

In Kenya, avocado is grown in several agroecological zones mainly by small-scale growers who grow them for subsistence, local markets, and export. Although Kenya has about 7,500 ha under avocado production yielding 81,000 t, about 30,000 to 40,000 t of avocado goes to waste annually on average.

Reducing post-harvest losses could save the economic resources and improve productivity of farmers and companies, increase the availability of food, and reduce the pressure on the natural resources needed to grow food ((Kumar & Kalita, 2017). In global food discards, the issue of post-harvest losses is particularly acute developing countries since it is there where avoidable post-harvest loss is the highest (Timmermans et al., 2014).

Therefore, food losses and waste should focus on the post-harvest, before reaching the consumer. By solving losses early in the food supply chain, the cost to the environment, society, and economy would be avoided. (Gustafsson et al., 2013).

Accordingly, the aim of this project is to investigate whether the technologies can be applied in avocados' post-harvest to reduce the waste and lead to more sustainable food supply chains (FSCs) in Kenya. The study will focus on four areas, including sorting, packaging, storage, and parts of transportation. By conducting literature reviews and interviews, this report will provide insights into Kenya's current status and avocado loss and waste reduction.

To do so, the main question and sub-questions have been defined.

The main question: What technology can be applied to reduce food waste and promote sustainable development of avocados in the export chain from Kenya to the Netherlands during the post-harvest phase?

Sub-questions:

- How the loss and waste of avocados can be reduced with technology during sorting when exporting from Kenya to the Netherlands?
- How the loss and waste of avocados can be reduced with technology during packaging when exporting from Kenia to the Netherlands?
- How the loss and waste of avocados can be reduced with technology during storage when exporting from Kenya to the Netherlands?
- How the loss and waste of avocados can be reduced with technology during transportation when exporting from Kenya to the Netherlands?

This report focused on suitable technologies that could be applied to reduce post-harvest food loss and waste of avocados in the food supply chain. Data and information were collected through semi-structured interviews with avocado importers, producers/exporters, packers and growers' associations, and knowledge institutions.

The report was structured as follows: Section 2 is the literature study, which focused on post-harvest waste and losses and potential technologies to reduce avocado waste in Kenya. Furthermore, it discussed the limitations of the literature, the potential challenges of these technologies, and the directions for further study. Section 3 mentioned the methods of this project. Section 4 presented the interviews about Kenya's current technological situation and useful technology. In Section 5, some discussions would be made to show the possibility and feasibility of applying the technologies. The differences between interviews and literature also were described in this part. Section 6 provided the conclusion. Section 7 presented suggestions for applying technologies well and reducing the waste of avocados. Finally, all references were listed in the last chapter.

2. Literature Study

2.1 Methods of literature study

Literature search, collection and presentation will be presented in this part (Literature study) including methods of literature study, results, discussion, conclusion and recommendations for the field research.

Table 1. *An overview of research methods for literature study*

Question	Specific information	Types of research	Search engines	Key words
1. How to reduce the waste of avocados with technology during sorting when exporting from Kenya to the Netherland?	Reduce waste by testing avocados for high quality and efficient sorting through non-invasive techniques	Literature study	Google scholar, Baidu, Inholland library.	Avocado; Sorting; Grading; Fruit waste of sorting; NIRs
2. How to reduce the waste of avocados with technology in packaging?	Packaging methods. Biological treatment. Chemical treatment	Literature study	Google scholar, Inholland library	Avocado; Technology; Perishable fruit; Packaging; Wax; Fungicides;
3. How to reduce the waste of avocados with technology during storage when exporting from Kenia to the Netherlands?	Temperature management. Delay ripening. Reduce respiration. Reduce ethylene production	Literature study	Google scholar, Inholland library.	Avocado; Post-harvest Technology; Storage; Respiration; Ethylene
4. How to reduce the waste of avocados with technology in transportation in Kenya?	The ways to reduce food waste from transporting perishable fruit.	Literature study	Google scholar, Baidu, Inholland library.	Avocado, Waste, Technology, Perishable fruit, Primary transportation, Primary package.

In **Table 1**, different questions correspond to different key words of detailed information.

To provide an overview of the usage of technology used in the post-harvest of avocadoes, a systematic review of articles published up to 11/13/2022 was conducted.

The literature search in academic databases was performed using the keywords ‘avocado', 'technology', 'sorting' 'packaging', 'storage', and 'transportation’. Searches were rerun using additional keywords identified from research keywords considered relevant to this literature study. Databases included Google Scholar, CNKI, Wikipedia, and Sci-Hub. Peer-reviewed articles were selected and screened for full-text availability. For instance, sub-question 1 is about the sorting methods for perishable fruits, and in terms of sub-question 2, is about some potential use technology for perishable fruit in packaging. For sub-question 3, investigating how can use technology to create suitable environmental conditions during storage. And finally, sub-question 4 is the physical damage and primary package during transportation. Research is based on the literature study. All the information is from professional pieces of literature and search engines.

2.2 Results of the literature study

In this Chapter, all the sub-questions which are mentioned in Chapter l, regarding the reduction of avocado waste in post-harvest, like transportation, sorting, packaging, and storage in Kenya, and export to the Netherlands will be answered through the literature study. Because onsite research is unavailable, the strategy used for this project includes two parts. First, the literature study helps form a basic understanding of the avocado chain and the technology and facilities used to prevent food waste. The second strategy is that through interviews online, the information needed which was not mentioned or incompletely in the literature study, and the newest status in Kenya's avocado chain will be collected.

The combination of literature study and interviews will give comprehensive instruction on how technology can be used to reduce food loss.

Overview of the general situation in Kenya's avocado chain

The product chain in Kenya ends up in consumers in various channels. There are two main flows, and they are the small-scale and large commercial (Rivera et al., 2017). In this project, the target part is from when avocados are harvested until they are transported to the exporters,

The export channel is organized with farmers and exporters, including cooperatives and export companies (Mendieta et al., 2016). The middleman and traders determine the price of the product. The whole chain has many participants from production to market. Most of the farmers work together with cooperatives. Cooperatives are the link between farmers and exporters. Some farmers are members and others are non-members of a cooperative and they both sell the products to cooperatives. Also, some farmers directly trade with exporter companies. After the trade between farmers and cooperatives. They trade the avocado to exporters. Since this channel has more participants than the large commercial one, the process is relatively more complex. Therefore, the way of reducing the loss of avocados in different sections of this channel is worth analyzing and being focused on (Snel et al., 2021).

The other way of dealing is the exporter directly collects the avocados without the help of cooperatives. This is the large commercial part. Most of the farmers do not use advanced technology in their production, harvesting and transportation. Transportation is done with open pickup and some avocados on the surface are directly exposed to sunlight. Local transportation is done with lorries without a cooling system. Some cooperatives have cooperation with the government which offers technical support and helps connect the cooperative and export company.

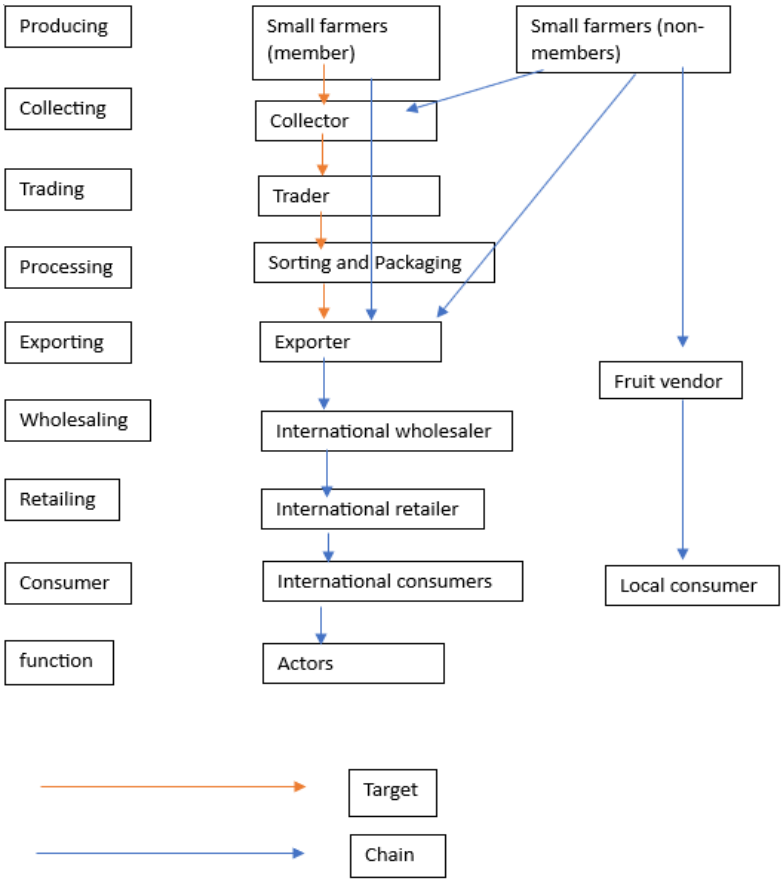

Fig 1*. The overview of the avocado supply chain in Kenya from the literature study.*

2.2.1 Reduce waste of avocado during the sorting

Currently 30% of avocados are wasted because of grading errors (Cranfield University, 2020). There are two main reasons for sorting waste in Kenya. The first reason is manual selection, and the second reason is the technology limitations.

First, labor lack training in Kenya during the manual selection process.

On the farm, unlike other produce, avocados cannot be judged ripeness by their appearance. Farmers are not trained professionally in Kenya, so many farmers are not able to judge correctly. They choose to harvest all avocados and then sort them by exporters. Meanwhile, avocados can be misclassified or suffer collision injuries due to unprofessional behavior (Clark et al., 2007).

After entering the depot, there are many steps in the sorting of avocados. The current situation in Kenya is that machines are not available in every depot. Large depots will choose machines to pick avocados. In some depots, avocados are selected by machine and manual together, and some small depots will be directly selected manually. In this case, people need to contact avocados. The quality will decline due to fatigue (de la Cruz, Jose Emmanuel Cruz & Ramirez, 2020). Meanwhile, due to the lack of professional training of labor in Kenya, manual operations may not correct to classify avocados. So, wrong judgments and operations by labor will cause avocados to be harmed and flow into the local market. For these reasons, there will be fewer avocados available for export in Kenya, and the farmers will increase the

cultivation volume in the next production, and the depot will increase the purchase volume. Such a vicious circle will lead to oversupply, and eventually many avocados will be wasted.

The second is the wastage of avocados due to technology limitations.

In Kenya, some depots choose to destroy avocados to measure the quality of avocados and sort them by testing the avocado pulp because mesocarp moisture content, peel moisture content, and dry matter content have been commercially recognized as indicators of avocado ripeness. To measure the levels of these substances, the pulp of the avocado is necessary. Since avocados are exported, this destructive measurement cannot be applied to all avocados and can result in the same batch being exported of different quality, leading to waste once it reaches the market (Magwaza & Tesfay, 2015). This method is useful but damaging to avocados and time-consuming. So, choosing non-invasive avocado technology in Kenya is necessary.

After reviewing several literatures, near infrared spectroscopy (NIR) is the generally chosen non-invasive technique for avocado screening. Infrared spectroscopy is used to classify avocados by measuring their dry matter. Meanwhile, near-infrared spectroscopy can not only measure dry matter, but also measure water and oil content. Since near-infrared spectroscopy can provide some bonding ratios, this information is not provided in previous avocado technology (Magwaza & Tesfay, 2015).

In 2011, a near-infrared assessment tool was developed to predict the durability of avocados by measuring their impact injuries and dry substance (DM). However, this measurement method has disadvantages, for the measurement time. The results would be more accurate 24 hours after the avocado was injured. So how to store avocados for 24 hours and keep them fresh is a challenge (Wedding et al., 2011). In another literature, the measurement time was also mentioned, the avocado would measure with 95% accuracy after 24 hours of storage. Avocados need to be stored 24 hours a day because the injured place will develop. Therefore, infrared spectroscopy is a technology that can be used, but requires storage time before measurement.

However, due to the variety of avocados and the growing place, the standard of DM measured by infrared spectroscopy is different. Hence, farmers have to take measurements of avocados grown in Kenya to get a spectrum. With the help of experts, the DM standard of avocados can be measured, so that avocados suitable for export can be screened through technology, thereby reducing waste.

Machines can solve avocado waste caused by manual and technology limitations. So far, there are machines with non-invasive technology, and a conveyor belt to send avocados to a series of operations such as cleaning, load bearing, selection, and processing to reduce human contact with avocados. Among non-invasive techniques, in addition to using infrared spectroscopy to select avocados, techniques such as magnetic resonance imaging can also be used.

Below is a picture of avocados being sorted by machine.

Fig 2. *Avocados are transported on a conveyor belt*

Fig 3*. Avocado sorting machine*

2.2.2 The packaging waste of avocado during post-harvest in Kenya

First, an overview of packaging is shown as the following figure.

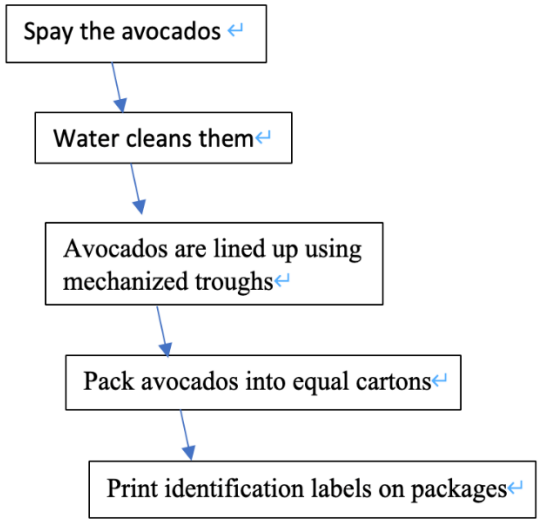

Fig 4. *Processes of packaging the avocados.*

Current status in Kenya regarding packing avocados

Post-harvest losses are mainly attributed to pulp softening, rotting, physiological disturbances, and improper temperature management (Kassim et al., 2013). The main cause of rotting is fungi.

In Kenya, after spraying the fungicide and taking the pre-protection, the clean and precise weight avocados will be lined up used by mechanized troughs. They are moved on the conveyor belt and put into the same cartons. Each carton may contain a different amount of fruit. Packing lines may cause bruising damage that leads to post-harvest losses. Collision losses often occur on avocado packing lines. The machinery and operations used in avocados (including fruits such as mango, papaya, etc.) may cause bruising damage that can lead to post-harvest losses. The bruises were mostly caused by collisions between the avocados and collisions between the avocados and the box. Collisions between avocados often occur at the junction of two conveyor belts. When the previous avocado has not been transported away, the new avocado has reached the designated position and hits it (Timm & Brown, 1991). Collisions with boxes Collisions occur when avocados land in boxes from the packing line.

For Kenyan avocados, each box is labeled with an identification tag before being refrigerated. Stickers document the exact fields and orchards where they were picked. The advantage is

that it helps the exporter to classify and confirm the order. At the same time, some companies mark the picking time of avocados on packaging. The advantage is that it can help warehouse personnel arrange them reasonably. Some companies, such as Halls, will use emerging technology-smart packaging. It leverages the communication capabilities of packaging to facilitate decision-making, with the benefit of improving food quality and safety (Gaona-Forero et al., 2018).

Examples of ways waste could be reduced in the packing

To delay the avocados getting rotten, preservatives and fungicides are usually sprayed on the surface of the avocado in the first step. One of the most common fungicides is Prochloraz. In the Kenya avocado industry, Anthracnose disease is a major production constraint of avocados. It leads to low avocado production and affects the marketability of the fruits both locally and internationally (Kimaru et al., 2020). Anthracnose disease is caused by Colletotrichum gloeosporioides, Colletotrichum Boninense, and Pestalotiopsis microspores both in the field and after harvest. It is associated with 60% losses that cause the abortion of fruits in the field and post-harvest roots (Kimaru et al., 2020). Some companies in Kenya currently use 200 ppm prochloraz acid + 50 ml HCl to control anthracnose. A combination of modified atmosphere packaging (MAP, 8% CO2, 2% O2) plus thyme oil (TO) was used to prevent the incidence and severity of anthracnose (Sellamuthu et al., 2013). Another report indicated that the essential oils lemongrass (LO) inhibited the growth of Colletotrichum gloeosporioides (Sellamuthu et al., 2013). In oil, geranial is the major compound. This method can be used as a synthetic bactericidal alternative, which meets organic requirements, and consumer acceptance, and reduces environmental pollution. To become more organic, some companies also use ozone treatment (Bill et al., 2014).

As for reducing the collision loss, the Instrument Sphere (IS) is used to record the effects occurring in the commercial packing line of these fruits. IS can identify transfers which cause significant impact in each packing line. All these line improvements can be achieved by adding cushioning on exposed steel surfaces, replacing worn cushioning, reducing height variations between components, and controlling fruit flow with each transfer. In a report about the effect of the acceleration of oranges on the packaging line, it was mentioned that there was an innovative machine that slows down the falling speed of the fruit due to the improvement of the metal chute and the presence of horizontal brush rollers (Timm & Brown, 1991). At the same time, the fruit is removed quickly with a conveyor belt, so that there is no collision. Compared with traditional machines, this innovative machine reduces acceleration, increases average speed, and physically avoids waste caused by collisions (Manetto et al., 2017).

Clear and comprehensive information not only reduces the load on the staff who check the quality of the avocados but also facilitates timely technical interventions such as ripening or refrigeration. There are three ways to preserve information. Printing barcodes on the packaging is the cheapest and most popular form of data. It contains a lot of data, such as packing date, batch/batch number, and package weight. As scanners have become more powerful and cheaper, QR codes have grown in popularity.

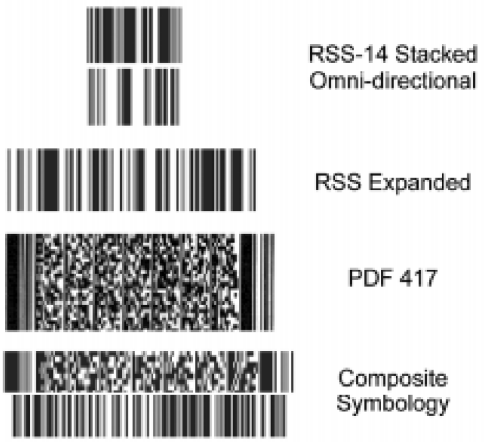

Fig 5. *Some kinds of barcodes. Note: Smart packaging systems for food applications: a review (2015).*

In Figure 5, PDF 417 (where PDF stands for Portable Data File) is a two-dimensional notation that carries up to 1.1 KB of data in one space. It can convey other information which linear barcodes cannot, such as nutritional information, cooking instructions, a food manufacturer's website address, and even graphics. The advantage of portable data is that they are immediately available without access to external databases (Biji et al., 2015). To provide even more functionality, the Uniform Code Council has also introduced a new symbology called composite symbology (Figure 2) that combines two-dimensional barcodes such as PDF 417 with linear barcodes.

2.2.3 Reducing the waste in storage of avocado

The storage includes three parts after harvest, on farms, during transportation and in deports. Spoilage and over-ripening are two main challenges in post-harvest, which lead to rapid deterioration (Snel et al., 2021).

Current status in Kenya regarding storing avocados

During storage, temperature and atmosphere content are the main factors affecting avocados' ripening process (Gross et al.,2016; The World Avocado Congress, 1998).

According to *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks Precooling* (2016), the respiration rate will go higher with the temperature rise.

Table 2. *Effect of Temperature on the rate of respiration /deterioration of Avocado*

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

Regarding atmosphere content, important elements that will impact the ripening process are CO2 and ethylene, they will promote the process of ripening and make products soften to decrease the quality (Feng et al., 2000; Hershkovitz et al., 2005).

However, in Kenya, most farms do not have precool facilities and leave avocados into the air temperature. Also, to decrease the cost, market agents would like to collect all avocados in

that area, which may take days to wait for. But these trucks do not have temperature-controlled systems. In addition, the lack of storage facilities in depots is a great challenge (Snel et al., 2021).

Examples of ways waste could be reduced in the storage

To reduce the effect of temperature, precooling is considered one of the most significant measures to maintain product quality. It happens before the product is sent to storage, which can efficiently help delay the ripening and softening after harvest (Gross et al., 2016). It is also called "First Mile Cooling". Generally, these avocados should be sent to the depot within 2 hours after harvest, the recommended temperature is 16 °C and even lower (Gross et al., 2016).

In depots, the general temperature in storage is 5-12°C and RH is 85-95% (Gross et al.,2016). Temperature Management was estimated to help reduce 30-60% of transport and storage loss (Snel et al., 2021), which pointed out the significance of having a temperature-controlled installation in the depot.

In terms of atmosphere, Controlled Atmosphere is useful to inhibit the ethylene by maintaining a low O_2 level and a high CO_2 level. Also, it can provide a low temperature environment to delay the ripening.

Coating is another way to control atmosphere content. One example is 1-Methylcyclopropane (1-MCP), a plant growth regulator, which can be used to inhibit ethylene synthesis and delay the onset of the climacteric peaks of CO_2 production. It can also help promote color development for early and middle-harvest avocados and make green avocados greener. In addition, it can protect avocados from cold injury (Hershkovitz et al., 2005; Mathe et al., 2018). The other example is the combination of waxing, LDPE, and temperature, which contributes to a decrease in cold damage, minimizes quality loss, decreases metabolism and ethylene production (Mendieta et al., 2016).

Regardless of monitoring parameters, there is a technology that can monitor the ripening process by analyzing the color and firmness. The system is based on Support Vector Regression (SVR), a supervised learning algorithm that can be used to predict discrete values (Cho et al., 2020).

2.2.4 Reducing the waste in transportation of avocado

Current status in Kenya regarding transportation

Loss or waste in transportation is one of the serious challenges in food supply chain management because of the handling and deterioration of the product during transportation activities (Gajanana et al., 2010). This is also a challenge for the avocado chain in Kenya.

For instance, the main causes of loss are those conditions that lead to the primary cause of loss. They are the result of inadequate or unsupported capital expenditure, technology and quality control (Atanda et al., 2011). And one of the main reasons is that lack of the technology regarding transportations for the transport and handling of perishable. In addition, a small number of farmers choose to use functional smart trucks which can adjust temperature during the way from their farms to the depots. The container on the truck has some sensors which can monitor the temperature, humidity, air condition etc. One of the most important avocado storage factors is temperature. Traditional temperature management has

always used installed thermometers. Regular temperature checks are required to manage thermometers. However, the temperature at the entrance to the warehouse and deep inside the warehouse tends to vary greatly because the opening and closing of the gate can cause the temperature at the entrance to vary greatly. As a result, thermometers installed in warehouses or trucks sometimes fail to record the correct temperature of the product (Asadi & Hosseini, 2014).

Examples of ways waste could be reduced in the transportation

Therefore, traceability systems in the food industry are very effective solutions to transportation challenges. To overcome these challenges, new technologies such as real-time and wireless are needed. Some of the new methods are described below.

Theoretically, Radio Frequency Identification (RFID) tags recorders are the perfect choice for temperature mapping and cold chain management of agricultural products. One area of automatic identification is RFID, which in its simplest form is like a bar code. It is seen as a means of enhancing data processing and complements existing technologies (Gandino et al., 2009). Using an "RFID tag" on an object and a "reader" to collect the tag information, RFID is an improvement over barcodes in many ways. Operational RFID systems include tags and readers that interact with object and database systems to provide information and/or operational functions (Rice, 1989).

The system used RFID diagram is shown in Figure 6. To create as many common solutions as possible to monitor the many different foods in transit, the cargo area (containers, trailers) is equipped with Raspberry units (which act as central processing units) and sensors for measuring temperature and humidity (digital or analog temperature sensors). The advantage of this system is that additional sensors can be easily added depending on special food monitoring requirements. In addition, the entire system is connected to equipment for scanning and reading cargo (boxes, pallets, buckets, etc.). The basic parameters (temperature and humidity) used for monitoring during transportation are identified, and the values are read from the sensor and the alarm is issued when the monitoring parameters are disturbed (Maksimovic et al., 2015).

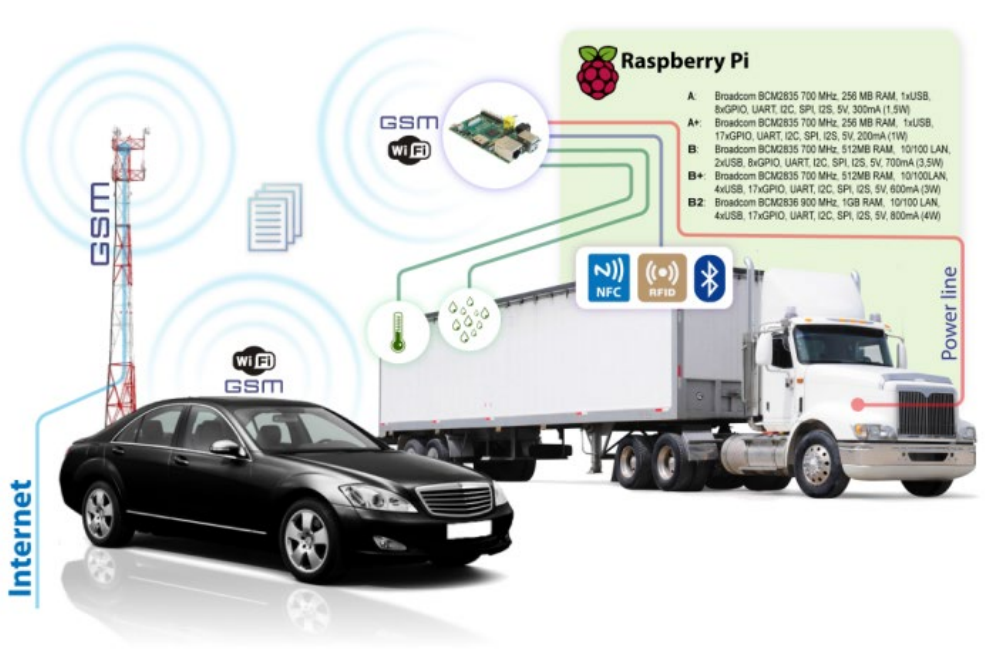

Fig 6. *Monitoring food safety during transportation (Maksimovic et al., 2015).*
The system can provide real-time monitoring parameters about food safety and trigger alerts when problems occur so that they can be caught before real damage occurs. The entire system can be powered by a car or an automatic battery (Maksimovic et al., 2015).

2.3 Discussion on the result

The results in this chapter were found from literature and all the sources found were reliable sources. Although some of the literature results had certain limitations because of being obsolete, and there were not enough relevant contents, which would be the main content of future research, the information in the results could be used to answer partly the main question and sub-questions. This paragraph discusses the results in depth.

2.3.1 Waste reduction during sorting of avocado

Although several references have been made to the application of NIRS to avocado selection, there is no standard spectrum to select from. This is because the spectrum is affected by seasonal and regional variations (Wedding et al., 2012). Calibration models for avocados can analyze data from multiple seasons and improve robustness by optimizing the pretreatment and wavelength regions as is done for mango (Anderson et al., 2020; Wedding et al., 2012). In terms of data collection, collecting the data from three harvest seasons can improve the accuracy, compared with using the data from one season or two seasons. And there is experimental evidence that sufficient data collection can improve robustness and allow fruit sorting (Rungpichayapichet et al., 2016). Avocados also apply to this theory, as the robustness of the model increases when the data includes a wider range of seasonal variations and regional data needs to be collected (Wedding, B. B. et al., 2013). This method of collection and analysis is not easy for farmers to understand. So, if it is possible, export companies can send experts to test and make standard spectra every year. And by teaching farmers how to use infrared spectroscopy to determine whether avocados are of high quality and reduce misjudgments, they could reduce avocado waste in Kenya.

Device	Intact fruit			Skin removed		
	R^2_C	RMSEC(%)	# f	R^2_C	RMSEC(%)	# f
F750	0.84	1.03	4	0.89	0.85	4
Micro-NIR	0.82	1.11	12	0.83	1.04	5
SCiO v1.2	0.59	1.72	4	0.82	1.08	5

Fig7. *Avocado fruit DMC PLSR calibration statistics for three handheld NIR devices (F750, MicroNIR and SCiO v1.2), using second derivative spectra of intact fruit and fruit with skin removed* (Subedi & Walsh, 2020).

Device	Intact fruit			Skin removed		
	R_p^2	RMSEP(%)	Bias(%)	R_P^2	RMSEP(%)	Bias(%)
F750	0.71	1.37	0.64	0.88	1.96	0.45
Micro-NIR	0.37	2.71	1.95	0.74	3.08	–1.74
Scio-v1.2	0.31	2.05	2.34	0.71	2.31	–1.89

Fig8. *Avocado fruit DMC prediction statistics for three handhelds portable NIR devices, using intact fruit and fruit with skin removed. Models were based on data of populations 6 and 8, n = 120, and used in prediction of population 9, n = 60* (Subedi & Walsh, 2020).

The two tables above show the results of the whole fruit and pulp of the avocados. Compared with the three machines, the F750 performed best.

F750 is the machine selected after literature study, but the core is portable and can replace manual selection machines. When this kind of machine is applied to Kenyan farmers and depots for selection, it can improve efficiency and reduce the waste of avocados.

After literature study, there are some information limitations. The sorting of avocados is limited in farms and factories, and other selection are not mentioned. Whether non-invasive technology could be applied in Kenya was not mentioned in literature. That information needs to be gained in interviews.

2.3.2 Waste reducing during packaging of avocado

In the result, ozone treatment is the most organic way to protect avocados in packaging process. However, the skin of avocados is too thick so that the ozone cannot penetrate the skin to reach the center. Therefore, ozone is likely to be deactivated only at the surface. To maximize the effect of ozone and minimize the damage, Karaca said that lowered temperatures will increase the solubility of ozone thus improving the degradation rate of pesticide residues. Increasing humidity and decreasing pH will augment the efficiency of the aqueous ozone (Karaca & Velioglu, 2007. Wang et al. 2001). It is indicated that the most rapid rate of mancozeb degradation is at pH 7.0.

The result mentioned many ways to exchange the information (PDF/ Barcode/ composite symbology). The information contained in the information is sorted from large to small: PDF> composite symbology> Barcode. The breadth of use is barcode> PDF> composite symbology (Vargas-Torrico et al., 2022). When Kenya choosing one of these ways, two aspects need to be considered. One is the content of the message that needs to be delivered. The other is the technology that exists in Kenya. All these need to be answered in the following interviews through Kenyan avocado exporters or Kenyan avocado supply chain experts. If the amount of information to be transmitted is large but the technology is backward, the barcode is a good choice. If the technology is advanced or Kenya actively invests in innovative technology, composite symbology, and PDF are both good choices.

To ensure the technology can be used in Kenya, the information about current statues and the penetration of technology in Kenya should be asked in the future interviews.

2.3.3 Waste reducing during storage of avocado

Applying new technologies to reduce Kenyan avocado waste presents several challenges.

One is the operation skills. According to Queensland Government (2014), Controlled Atmosphere requires high skills to operate the system. As a high technology, monitoring ripening process also faces the challenge. However, the specific information of operation level is unknown in Kenya.

Also, the accessibility of proper facilities will cause difficulties on do pretreatment based on waxing LPDE and temperature, since Kenya avocado production is based on the small-scale farmers. For those bigger growers, these pretreatments will help reduce the loss during storage (Snel et al., 2021).

Additionally, the use of 1-MCP to inhibit the ethylene synthesis has a problem of non-organic, which may limit its application due to the requirements of organic fruits (Malesic, 2018).

Further study should be focused on the practical situation in Kenya because the information about Kenya avocado chain founded is not sufficient. Except for the storage condition and precooling, taking some measures in advance can help expand the storage time. However, according to the literature, it is difficult to find compatible literature describing the corresponding measures taken Kenya in the storage phase for avocados.

Also, the situation of machines, installations and required operation level in Kenya and chemical issue will affect the application processing. The interview with Kenyan experts and export companies will provide information leading to further study to see how the storage can be optimized.

2.3.4 Waste reducing during transportation of avocado

Since the above system is aimed at the use of raspberries in the actual supply chain, can RFID technology be applied to the transport of avocados in Kenya as well as the entire supply chain?

The answer can be positive. Because the first to be identified is that RFID has been proposed as a leading technology that can help reduce waste in the perishable food supply chain (Grunow & Piramuthu, 2013). As well as offering attractive opportunities to improve information flow management within the supply chain and the safety of the agri-food sector (Costa et al., 2013). And avocados and raspberries are perishable fruits with a relatively short shelf life. This greatly improves the possibility of using RFID technology in the avocado transport chain. Provides attractive opportunities to improve information flow management within the supply chain and the safety of the agri-food sector.

2.4 Conclusion from the literature

Post-harvest waste in the avocado supply chain is from a range of factors, including manual handling and technical limitations in sorting, physical damage during packaging, inadequate storage conditions, and insufficient transportation operations. To address these issues, various techniques have been developed and implemented in the industry.

To measure avocado quality after harvest, both invasive and non-invasive techniques can be employed. Non-invasive techniques can help reduce waste and ensure consistency in quality. For instance, machines such as the F750 avocado quality meter can replace labor and optimize the selection process. To avoid ripening and keep quality in the avocado supply chain, various techniques are commonly used, including ozone treatment, fungicides, pre-packaging wax, low-density polyethylene, and coating. Additionally, collision-reducing machines, pallets, track systems, and monitoring are utilized as well. To keep the avocado quality at a relatively high-level during storage, CA and 1-MCP are two possible technologies that delay the ripening process. In order to maintain traceability in the avocado supply chain and avoid unnecessary waste, RFID can be used throughout the supply chain.

While these techniques offer an improved supply chain and environment for avocados, limited literature exists on the corresponding measures taken in Kenya's avocado industry. Therefore, further research is necessary to explore the status of technology in the various phases of avocado production and distribution in Kenya.

2.5 Recommendations for field research

Based on the findings from the literature study the team focused on the following points for the interview phase of the project. Some aspects of sorting, packaging, storage and transportation can reduce waste, which was not covered during the literature survey, and further investigation is required after the interview.

- Although some technologies mentioned in the literature are related to avocados, the possibility of implementation and popularization in Kenya needs to be analyzed after knowing the current status of the avocado chain in Kenya during the interview.
- The difficulties when applying the technologies should be asked in future interviews.
- The other factors influencing the applied technologies should be answered in the later interviews and discussed.
- The effect of using chemicals should be discussed in the interviews.
- Some aspects of sorting, packaging and transportation can reduce waste, which was not covered during the literature survey, and further investigation is required after the interview.

3. Methods

Sources were from interviews with experts in Kenya and the Netherlands and exporters in Kenya. There were three online interviews conducted during the research. The first interview was carried out on 20/11/2022, with the supply chain expert at Wageningen University. the second interview was held online on 29/11/2022, with Hass (a big international avocado company in Kenya). The last interview was carried out on 16/12/2022. The expert Victor was invited to join this online meeting and provide practical information.

Table 3. *An overview of interview questions for several interviewees*

Questions	**Specific information**	**Key words**	**Ways of interview**	**Interviewee**
Overall questions for Kenya situation.	Some of the technology used in perishable fruits and which type of new technology can be used locally in Kenya.	Technology, Supply chain, perishable fruit,	Online-Email and Microsoft Teams	The professor from Wageningen University
Basic avocado information for Kenya. Specific information for each sperate sub question.	Causes of waste in production, sorting, packaging, storage and transportation of avocados during supply chain. Current and potential solutions to food waste.	Technology, Avocado Sorting, Packaging, Storage, Transportation	Online-WeChat	Lifan Yu from Halls (Avocado exports company in Kenya)
Basic avocado information for Kenya. Specific information for each sperate sub question.	On the basic waste situation of Kenyan avocados sorting, packaging, storage and transportation, As well as a description of the technology used locally and an explanation of the feasibility of potential technologies.	Technology, Avocado Sorting, Packaging, Storage, Transportation, Possibility	Online-Email and Microsoft Teams	Victor Kiplangat from Kenya

Table 3 shows the overview information of interview including questions, specific information, key words, ways of interview and interviewee. The interviews were conducted via online meetings and further supplementary information was provided via email. Questions are related the technology used in perishable fruits and which type of new technology can be used locally in Kenya.

4. Results

Overview of current statues in Kenya

The avocados are picked by local farmers first. Usually, avocados are put on the orchard ground for 2-3 days. Most of the orchards are small-scale. In the previous time, middlemen will buy avocados from farmers and sell them to the company. But now, these kinds of farmers group themselves and try to get the best exporter who can come and buy the fruits from their farms.

To export Kenyan avocados, HCDA export license, phytosanitary and conformity certificates from KEPHIS, Global GAP Certification, MRL limit compliance, and BRC certification from Kenya Plant Health Inspectorate are required. Euro 1 Certificate also is coming.

When all the avocados are picked, the company or exporter will use pickup tracks to transport the avocados from farms to depots. When the avocados reach the depots, they will be sorted into three classes. First class means that it can be exported or sold in the domestic market. In the second and third classes, most of the avocados will be processed into soaps or other chemical products. Qualified avocados will go through cleaning, quality control, packaging, and storage. Then they can be transported to the Netherlands.

Ships are the most common ways to transport avocados from Kenya to the Netherlands. Exporters use metallic containers in the ship and pellets inside.

Many people think the use of modern technology in the storage of avocados in Kenya is an essential step in optimizing the supply chain and increasing the efficiency and profitability of the avocado industry. As the avocado industry in Kenya continues to grow, modern technologies are crucial in reducing losses and improving the quality of the fruit.

Many farmers and exporters in Kenya are aware of the benefits of modern technology in storage and they are looking to implement new technologies to optimize the supply chain. However, the adoption of modern technology in the avocado industry in Kenya can be affected by various factors such as cost, the availability of technology, the need for more technical knowledge, and regulations.

This is the current state of a part of Kenya's export chain, from farms to Dutch ports. There are many challenges and infinite possibilities in this.

4.1 Sorting in the export chain

During the interview, the sorting process of avocados in Kenya was mentioned. Meanwhile, in addition to technical limitations and manual operations, the two reasons that lead to the waste of avocados mentioned in the literature study, there are also economic reasons. Economic problems prevent some companies from buying machines and farmers choose to deal with middlemen. The table shows the information collected in three interviews.

***Table 4**. Interviews about sorting of avocados in Kenya.*

Sorting	Interview 1 (Wageningen)	Interview 2 (Halls)	Interview 3 (Kenyan Experts)
Challenges in current statues	1. Unprofessional manual operation 2. Technology limitations	1. Not unified standard for avocado grading. 2. Challenges of oversupply.	1. Middlemen 2. Many of the machines that could replace human labor are not being used by export companies in Kenya due to economic reasons. 3. Farmers income

			4. Not unified standard for avocado sorting.
Examples of current technology	Non-invasive technologies (techniques that don't harm avocados) have also been mentioned, and near infrared spectroscopy and computer imaging are relatively mature technologies that could be deployed in Kenya.	Hass has its own avocado fields, so it doesn't need to buy from farmers. But Hass will hire Kenyan farmers to grow it.	1. Commonly used avocado grading standards in Kenya (Standard high to low): a. Extra fancy: These are the highest quality avocados, with the best size, shape, and color and the least amount of blemishes or damage. b. Fancy: These avocados are slightly lower quality than extra fancy, with a few more blemishes or imperfections. c. No. 1: These avocados are lower quality than fancy, with more blemishes or imperfections, but are still considered suitable for sale. d. No. 2: These avocados are of the lowest quality and may have more significant blemishes or imperfections. They may be used in processed products or sold at a lower price.
Potential areas using of technology in future	Promoting non-invasive technology for widespread use in Kenya.	/	/

4.2 Packaging in the export chain

In terms of packaging, the 'materials' 'density' 'rotten and bumping loss' 'operations', and 'information' are the keywords in this part. The important and detailed insights and solves are shown in Table 5. The table shows the information collected in three interviews.

Table 5*. Interviews about packaging of avocados in Kenya.*

Packaging	Interview 1 (Wageningen)	Interview 2 (Halls)	Interview 3 (Kenyan Experts)
Prob in current statues	1. Poor packaging causes avocados to get bumping damage. 2. Overloading 3. Getting rotten	1. Not unified standard for avocado trading. (Small orchards and large orchards) 2. The position of the avocado in the box is not suitable. 3. Avocados may not be the most desired state for customers when being received.	1. When the avocado is damaged, the staff cannot find it in time. 2. Avocados are transported by conveyor belts and selected into boxes by workers. Collision waste often occurs when avocados pass through the junction of two conveyor belts and from conveyor to box.

Examples of current technology	1. The number of avocados per box is limited. 2. When the avocados reach the depot, workers usually use hot water to clean the fruit. 3.Using pesticides during picking.	1. The density of packaging is based on the different customers' needs. 2. Supermarket orders: Techniques to slow the ripening or rotting of avocados. Restaurants orders: Ripen avocados. 3. Small-sized packaging materials will be changed from plastic boxes to cartons that can be recycled.	1. Modified atmosphere packaging (MAP). 2. Intelligent packaging and innovative packaging is designed to monitor the condition. 3. Fungicides: Benomyl and Propiconazole. 4. High-quality packing materials help cushion the fruit and prevent damage during transport. 5. Appropriate packaging for the size and weight of the fruit: This can help distribute the fruit's importance evenly and prevent damage from shifting or bumping. 6. Proper handling techniques: Careful handling during packing can also help to prevent bumping damage. This can include gently placing the fruit in the packaging and avoiding rough handling or stacking the fruit too heavily. 7. Inspecting the fruit for damage before packing: Any fruit that is already damaged should be removed from the packing to prevent further damage to the rest of the fruit.
Potential areas using of technology in future	1. Optimize the organization of the supply chain itself. 2. Using technology to help young generations get the operation skills and knowledge.	1.Technology of biodegradable materials 2. Other technology for minimizing the impact of packaging on the environment.	1. Technologies to export organic fruit. 2. Kenya now needs to achieve is that when customers get a bad avocado, they can track exactly which orchard the avocado was harvested from, by whom, and when 3. Using technology to complete the information chain on the packaging.

4.3 Storage in the export chain

In terms of storage, the keywords include “storage facilities” “storage parameters” “local regulations” “cost” “operation” and “modern technologies”. The table shows the information collected in three interviews.

Table 6*. Interviews about storage of avocados in Kenya.*

Storage	Interview 1 (Wageningen)	Interview 2	Interview 3 (Kenyan Experts)

Challenges in current statues	1.Lack of temperature-controlled storage facilities. 2.Concentration of ethylene should be focused. 3.Labors are lack of operational skills and knowledge, which will be a challenge to introduce new technologies. 4. The cost of technology will be a barrier.	/	1. The percentage of avocados lost during storage ranges from 5-10%, maintaining the proper storage condition is the most important to reduce food loss. 2. Avocados will be kept on farms less than 4 days to wait for companies or market agents to pick them up. 3. Small-scale farmers don't have any precool measures. However, avocados should be kept in cool and dark areas after being picked. 4. Hard to set a single standard for all depots, due to the different varieties, farms' location and market demands. 5. Coating may affect the taste and should be used to abide by the local regulations. 6. Poor storage infrastructure, lack of proper cold storage facilities 7. The cost and the regulations should be taken into consideration 8. The only way that technologies will be useful is to be combined with good agriculture practice.
Examples of current technology	/	/	1, Large-scale producers will pick up avocados and transport them to the pack house immediately and precooling is well operated 2. Controlled Atmosphere has been used widely in Kenya. 3. Kenya uses 1-MCP to inhibit the ethylene synthesis to delay the ripening process and extend the shelf life. 4. There are already some technologies to monitor the parameter (temperature, humidity, oxygen levels, carbon dioxide levels, and ethylene levels) of the storage
Potential areas using of technology in future	/	Exporters in Kenya are willing to invest in new technologies to improve the quality of avocados	1. New methods of controlling the environment in storage facilities, new methods for monitoring and analyzing data on storage conditions. 2. Artificial Intelligence and Machine Learning are considered.

4.4 Transportation in the export chain

In terms of transportation, the key works would be "smart containers", "RFID", "ICT", "Block chain". The table shows the information collected in three interviews.

***Table** 7. Interviews about transportation of avocados in Kenya.*

Transportation	Interview 1 (Wageningen)	Interview 2(Halls)	Interview 3 (Kenyan Experts)
Challenges in current statues	1. Cold storage is not always in use. If so, it is often an international company doing the logistics.	1. The biggest wastage of avocados is in long-distance shipping (both from Kenya to the Netherlands) and in containers 2. Shipping was not timely and on time because of the epidemic 3. The lack of timeliness and preservation technology in the way of transportation.	1. The distance from the factory to the farm is about 250-350km and considering the road conditions near the farm in Kenya, it is quite a distance. 2. Normally, exporting companies wildly use trucks to transport avocados and other fruits in Kenya.
Examples of current technology	1. Normal containers	1. Normal containers 2. / 3. /	1 and 2 regular pickups a
Potential areas using of technology in future	1. The cold storge system during the transportation (smart containers)	1. Smart containers 2. Information technology (ICT) 3. Food traceability technology (RFID)	1 and 2 smart container trucks a (reefer containers and block chain b)

The following points (mentioned in Table 7) need to be explained:

a. The difference between container trucks and regular pickups is clear. The system has the advantages of small size, strong flexibility, fast system expansion, real-time access and automatic identification of goods. However, future research will focus on connecting vehicles, sensors and mobile devices to a global network to provide a variety of services for vehicles and transport systems and the people in and around them (Maksimovic et al., 2015), which can easily be adapted for long distance local transport from farm to warehouse.

b. Meanwhile, the blockchain from (Table 7) is using blockchain technology to track and trace the avocados through the supply chain, providing transparency and traceability for the consumer and allowing for better inventory management.

5 Discussion

5.1 Sorting in export chain

In the previous literature study, the part about sorting in Kenya focused on farmers and depots, but the connection between farmers and depots was not mentioned.

After the interviews, a flowchart for the selection was drawn. After farmers receive avocados in Kenya, there are two ways to export them. The first type of farmer has a direct connection with the export company and sends the avocados to the depot for processing and selection, and the second way is through a middleman. In this case of additional transportation, selection and extended time, the avocados are sent to the depot. Depots are generally divided into three types. The first is to select the avocados entirely by hand. The quality is judged by weight, appearance and other factors which conclude that the avocados are ready to be exported. The second is machine selection, where the avocados are placed on a conveyor belt. The machine carries avocados for various processing. After being cleaned and weighted, they are sent to the machine scanning place for re-screening, and those of poor quality are sent to the local market. The avocados that can be exported are quarantined, packed and stored, waiting for export. The third is the combination of machines and humans for processing and selection. Some steps, such as checking the weight and size of avocados, will be completed by humans.

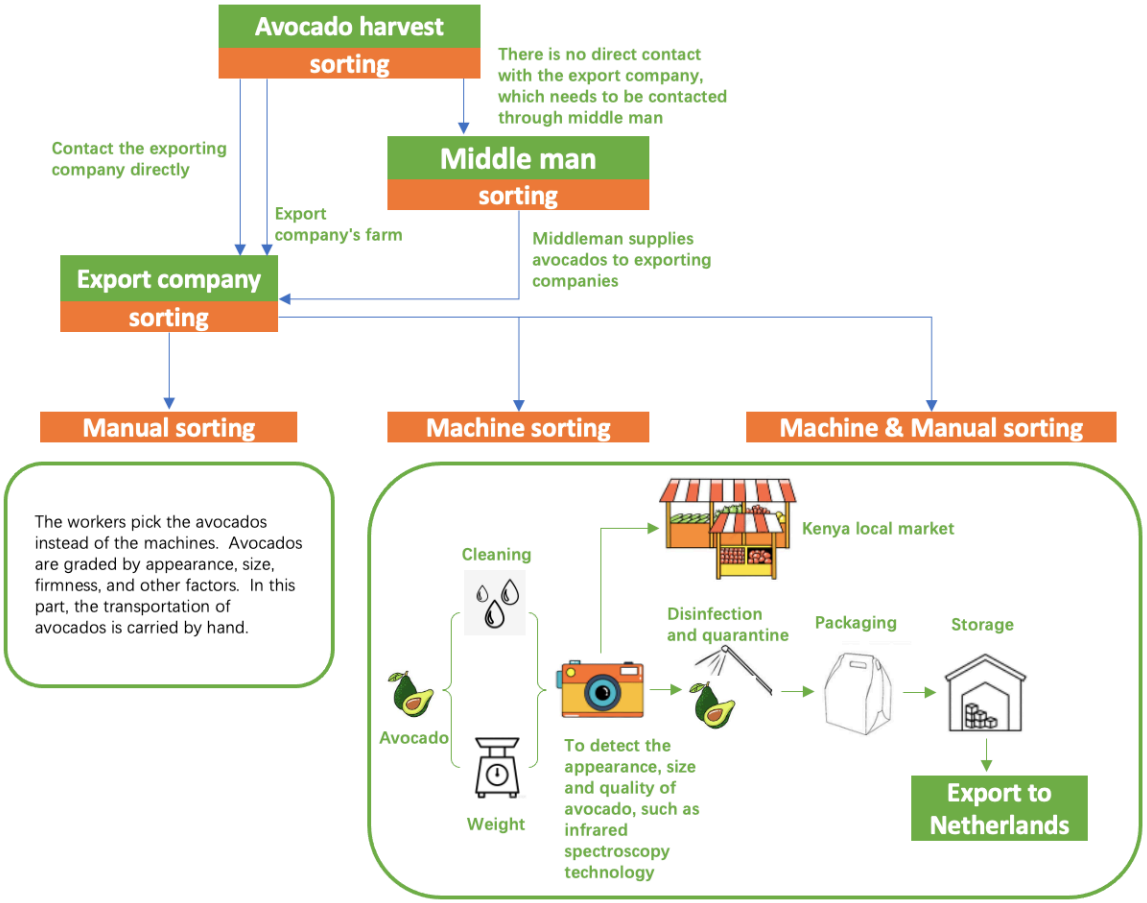

Fig 9. *The process of avocado sorting in Kenya*

Infrared spectroscopy was also mentioned in Literature study. In this technology, data measurement, avocado measurement method is a complex operation and technology for farmers and ordinary workers. At the same time, if new technologies are to be introduced, staff changes and factory process changes will be a big challenge for Kenya. So, experts are

necessary. Simple machine operations can be performed by local Kenyan staff, but technical and data measurement requires expert help to reduce operational difficulty and steps.

In the previous literature study, it was mentioned that some companies did not purchase machines due to machine reasons. Economic problems exist not only in companies, but also in farmers. But many middlemen do not have professional operation and knowledge, in the selection process will be in low quality and low efficiency and cause waste. In this case, the elimination of middlemen is necessary, and farmers need to be taught the right knowledge to operate avocados. But the reason why middlemen are proliferating in Kenya is that farmers need money for daily life. Therefore, export companies can help farmers, if possible, by paying a part of the deposit so that farmers can make a living and learn professional knowledge after selection. Export companies that send professionals to help farmers are also sustainable, receive high-quality avocados and help local growth. Also in that way, avocado would reduce waste in Kenya and boost farmers' incomes. In interviews, Halls mentioned that they employ Kenyan farmers to grow avocados. Employment relationships between export companies and Kenyan farmers can also reduce waste.

5.2 Packaging in export chain

Spraying is the first and one of the most important steps during packaging. Now, most of the exporters use Sportak, which can prevent diseases from avocados and make fungi actively be far away from the fruit. In this case, avocados could be more attractive and popular, also exporters can earn more money. However, consumers now more and more prefer organic fruits. It has been a main storm in society. In interviews, experts have mentioned that reducing post-harvest time and keeping avocados always at the correct temperature are both good ways to solve this problem. Kinds of literature show the most common way is Ozone treatment.

The EU chemicals policy model can analyze the sustainability of fungicides and pesticides. In the EU chemicals policy, most of Kenya's avocado exporting processes have met the basic requirements—safe and sustainable chemicals. The fungicides Prochloraz have no negative effects on the environment (Vijay Rakesh Reddy et al., 2022).

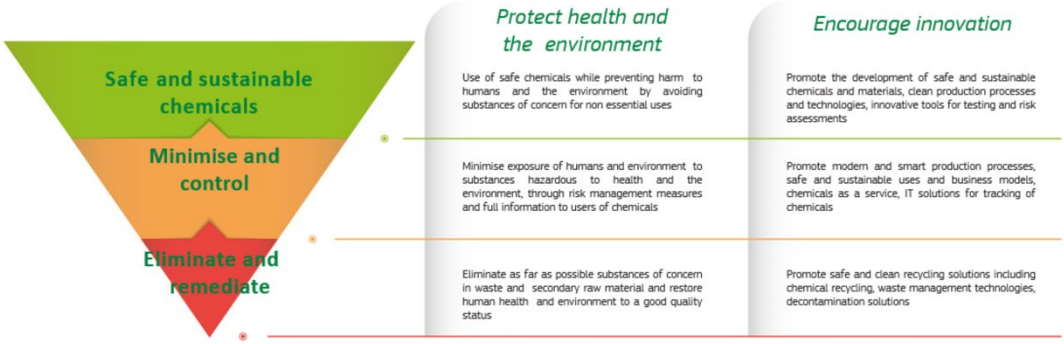

Fig 10. *Towards a toxic-free environment: a new long-term vision for EU chemicals policy (2020).*

For a new generation of workers to learn to operate innovative machines, it is necessary to hold systematic training. This cannot be achieved without the guidance of advanced technical personnel (Fenko et al., 2015). Kenya needs to introduce talents and technologies from developed countries such as the United States, the Netherlands, and Germany, and establish

learning channels for farmers, such as agricultural cooperatives. Some Dutch companies such as Fairtrasa already have such cooperation with Kenya. Fairtrasa teaches organic agriculture to smallholder farmers in Kenya. And it organizes group training and community events, and in-house agronomists pay regular field visits, where they provide personalized support. In Peru, Fairtrasa also runs a morning program on the local radio, which helps farmers understand how ecological practices serve their best long-term interests. Moreover, it teaches organic methods and supports growers and co-operatives in managing their certifications. Certified organic farms have better sustainability performance than non-certified farms due to greater economic resilience, environmental integrity, and better support and training for workers (Kamau et al., 2022). With the help of these big foreign companies, more and more certified organic farms appear so that innovative machines can be used, and young generation workers have the opportunity to touch new machines.

5.3 Storage in the export chain

The outcome of this research has provided insight into the technology used in the avocado storage in Kenya.

The results of the interviews were same as the results from literature: cold storage facilities and storage parameters are important to maintain the quality of avocados.

The continuity of the cold chain is essential for Kenya. It means there should be cold storage facilities at any part of the supply chain, including on farms, during transportation and in depots (Snel, et al., 2022).

However, as the interview and literature showed, lacks precooling facilities is a great challenge for Kenyan farmers. According to the interview with Kenyan experts (Interview 3), these fruits should stay under cool and dark environment. Considering the cost and facility accessibility of small-scale farms, charcoal cooler might be an effective and economical solution (Snel, et al., 2022). In recent years, cold stock treatment (CST) was proven to be used as precooling measure by putting avocados in ice water for 30 minutes, which also has no requirements on specific facilities (Chen et al., 2017). For the storage facility, although the lack of cold storage is a big challenge, many exporters already have temperature management in their depots, the next step is to expand the usage.

During storage, from the result of literature and interviews, it's necessary to control the contents of the environment, especially for ethylene. Controlled Atmosphere (CA) is an essential technology, which is widely used in the avocado industry. Also, there are already some exporters monitoring the environmental factors. Based on it, it's possible to apply technology that can monitor the ripening process. However, as the Wageningen University and Kenya experts said, the application of new technologies requires the operation skills and knowledge. The cost is also a big challenge. It's much easier for large-scale producers to introduce these technologies in their companies, due to the consideration of capital and education.

To apply technologies, local laws and regulations should be taken into consideration. For 1-MCP, in Germany, it can only be used for apples, which means the scope of application is limited (Dust & Eurofins SOFIA GmbH, 2012). Regarding the missing point in the interview, the application of the combination of waxing, LDPE, and temperature is facing the same challenge as 1-MCP.

According to the model from Action Contre la Faim International (ACF) (2014), regardless of the original quality of products, there are three extra elements that should be focused on to keep the quality during the storage: temperature, relative humidity (RH), and environmental conditions. The original quality of fruits is the quality before putting into the depots, which is the most important factor.

Table 8. *Possible Technology according to the Model*

Elements	Situation in Kenya	Possible Technology
Original Quality	On farms, Kenyan farmers almost have no cooling facilities to control the temperature after harvest to over the period of waiting for transport, which may affect the quality.	Precooling
Temperature	The storage facilities in Kenya now need to be improved. As for exporters, they invested and are willing to invest in temperature-controlled facilities.	Temperature Management; Controlled Atmosphere (CA)
Relative Humidity (RH)		
Environmental Conditions	There are already technologies that can be used to monitor the content and concentration of environment in storage. They focus on this area and would like to invest in new technologies for AI and MS to analyze and alert.	Controlled Atmosphere (CA); Monitoring ripening process during storage

Controlled Atmosphere is equally important before avocados are transported to depots and in the depots (Arias Bustos & Moors, 2018). From the table 8, it can meet the requirements of monitoring temperature, RH, and environmental conditions, which includes the three elements of the model. Therefore, it would be essential for Kenya to reduce food waste and enlarge the application of Controlled Atmosphere.

5.4 Transportation in the export chain

Comparing the results in literature study and interview part, there are several points that should be discussed.

The most important missing point which caused most waste in the literature study is long-way transportation on the sea. Products like avocados with limited shelf-life demand high-frequency shipments. While Marine solutions provide adequate shipping time, delays due to low ship frequency and inadequate container functionality can result in significant waste (Jedermann et al, 2014).

So, the choice of intelligent container is very important. The prototype of the 'intelligent container' was tested for the supervision of the transportation of bananas from Central America to Europe in one case study (Jedermann et al., 2014). Bananas have the characteristic feature of continuing to produce large amounts of heat by respiration processes after being harvested. One important finding was that less than 10% of the available cooling capacity of the unit arrives at the bananas in the center of a pallet load. The cooling efficiency could be improved by as much as 50% with better packing and loading schemes (Jedermann et al., 2014). It turns out that bananas stored in intelligent containers can maintain better quality and thus reduce waste.

Therefore, continuous temperature and quality monitoring is very important for fruit container storage. However, it is important to note that even when best practices are identified and implemented, there are inevitable variations in post-harvest handling due to weather, supply spikes with limited manpower, etc. Due to the inevitable changes in some cold chain processes, time and temperature data collection, coupled with automated calculations of changes in shelf-life loss, will continue to yield significant process benefits in real time while reducing avoidable shelf-life losses. In order to maintain the efficiency and effectiveness of the production process as much as possible, it is necessary to conduct ongoing audits based on current and past temperature and quality data.

Furthermore, through better control of post-harvest conditions, alternative modes of transport can be employed. The transport capacity in specialized reefer vessels has been declining since 1994, whereas the containerized fleet has increased by a factor of 10 and is now providing 90% of the overall reefer capacity (Arduino et al., 2015). Many bulk fruits are gradually moving towards containers, especially intelligent containers.

So, what is the feasibility of intelligent container in the Kenya-Netherlands avocado supply chain?

The answer should be positive or even yes, some companies are very willing to accept this technology used in the supply chain and have expressed a strong willingness to do so. The benefits of reducing food waste from avocados outweigh the costs. Companies can apply these intelligent containers to trucks and ships. But it's very difficult for local farmers in Kenya; Because they lack the capital to support the container in the trucks. Therefore, it can be concluded that intelligent containers can be introduced by companies and cooperate with farmers to make efforts to reduce more avocado waste.

6. Conclusion

According to the information from all interviews, it is noticeable that Kenya faces lots of challenges during the post-harvest phase. In general, the lack of knowledge, employee training, non-technology packages, and temperature-controlled facilities are the main challenges in the post-harvest phase. However, the existing problems have some potential technologies to avoid them.

Initially, training people is necessary at every step of the supply chain, which can significantly avoid and decrease unnecessary manual waste.

For sorting, non-intrusive technology needs to be introduced. If it is not possible to purchase a machine to perform the complete processing steps, portable machines and picking machines can be used to replace the labor, thereby reducing waste.

Moreover, the workers need to pack a certain number of avocados in specific packages including cartons, plastics (biodegradable/non-biodegradable), pure kraft paper, and wooden boxes which are the common packaging materials. Innovative packing machines can be used to reduce bumping damage in the packing line.

Furthermore, controlling storage conditions is also indispensable. During the storage, temperature, RH, and environment are three elements to control the quality. In that case, pre-cooling, temperature management, CA, and monitoring ripening process are four technologies that can used to reduce the damage from hot climates and ethylene. And at the same time, the stakeholders in the supply chain can select smart containers to control important elements for reducing transportation waste.

Although there are several potential technologies that can improve the current situation in Kenya's avocado supply chain, cost remains a limiting factor of introducing and developing them. While purchasing new technologies may be expensive, it is outweighed by the benefits of applying them. Therefore, the possibilities and feasibility of using the potential technologies are quite high.

7. Recommendation

In general, the following recommendations can achieve the technology applied in Kenya to some extent:

- As the basis of applying new technologies, Kenya should actively look for opportunities to communicate and cooperate with large companies in developed countries and ask them to provide organic & regenerative training.
- Eliminate the middleman. Exporters and farmers are in direct contact, providing technical and economic assistance to support farmers' daily life and satisfy their needs for 'quick money'.
- To solve the problem of cost for small-scale growers in introducing technologies, the government or organizations should support them financially to install facilities if possible.

There are also more specific recommendations for each aspect (sorting/ packaging/ storage/ transportation):

- In terms of sorting, introduce non-invasive technology to test the quality of avocados to replace labor. Such as infrared spectroscopy.
- As more and more consumers resist direct spraying of insecticides and fungicides, Ozone treatment instead of fungicides can be used.
- During storage, it's necessary to focus on technologies that can reduce the concentration of ethylene, which can prevent quality deterioration.
- Small-scale growers can use the charcoal cooler as their precool facilities on farms. As for cold facilities, they can set a cold storage where they live in groups, so that these avocados can survive from the hot weather when waiting for companies to transport them.
- Using functional containers and sensors which can continuously audit.
- For unavoidable deviations should be handled by dynamic measures, i.e., intelligent quality supervision, intelligent stock rotation to keep the process as efficient and effective as possible.

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