Discussion paper on current food safety gaps, food losses and improvement options

Deliverable 4.1 | HealthyFoodAfrica

Healthy FoodAfrica

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Summary

This report is a discussion of the food loss or waste and food safety challenges and gaps in postharvest handling practices and technologies (WP4), as well as a review of the current technologies used in the fruits & vegetables, fish & poultry supply chains of the Food Systems Labs (FSL) within the framework of HFA project. Largely based on literature and limited primary data from FSLs, the report has identified food loss challenges and gaps, given estimates of the extent, causes and consequences of food loss in the FSL's countries for the selected supply chains, as specific data for the FSLs is scarce. The report has also discussed the food loss assessment methodology and recommended one for use in the FSLs. On the food safety front, the report defines food safety and also highlights health, trade and economic impacts of food safety challenges. In addition, the report identifies some food safety challenges and gaps in the FSLs based on literature and limited information from key informants. Therefore, the report justifies the need for collection of baseline data on food safety and food loss in the FSLs to better appreciate the highlighted gaps and challenges. The report proposes some post-harvest improvements in terms of practices and technology interventions in the selected supply chains in the FSLs. On this aspect, to ensure high adoptability and sustainability, the report emphasizes the need for co-creation of innovations with the actors in the food supply chains of the FSLs, to mitigate the food safety and food loss challenges and gaps. Finally, the report has proposed some food safety and food loss indicators, which can be collected at baseline and be used to gauge the success and/or impact of the HFA project after interventions in the selected FSLs.

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Acronyms

AMR	Antimicrobial Resistance
CAC	Codex Alimentarius Commission
COMESA	Common Market for Eastern and Southern Africa
EU	European Union
FAO	Food and Agriculture Organization
FSL	Food System Lab
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GHP	Good Hygiene Practices
GMO	Genetically Modified Organisms
GMP	Good Manufacturing Practices
GVP	Good Veterinary Practices
HACCP	Hazard Analysis of Critical Control Point
IFPRI	International Food Policy Research Institute
OECD	Organization for Economic Cooperation and Development
PRP	Prerequisite Programs
ISO	International Organization for Standardization
SOP	Standard Operating Procedures
SMEs	Small and Medium Enterprises
SPS	Agreement on Sanitary and Phytosanitary Measures
SSA	Sub-Saharan Africa
SADC	Southern African Development Community
WHO	World Health Organization of the United Nations
WP	Work Package
WTO	World Trade Organization of the United Nations

Important definitions

Biological hazard	Threat posed by living organisms
Certification	Procedure by which a third party gives written assurances that a product or a process is in conformity with a corresponding standard. With certification, a product or process may be labelled as certified.
Certification body	Third party institution that carries out the certification programme and issues and delivers the certificate. Certification bodies may execute several different certification programmes.
Chemical hazard	Threat posed by chemical substances / agents
Disinfectants	Chemical agents applied to surfaces to inactivate or destroy microorganisms
Foodborne disease	Diseases, usually either infectious or toxic in nature, caused by agents that enter the body through the ingestion of food
Food hazard	A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect on the consumer
Food safety	Assurance that food will not cause harm to the consumer when it is prepared and/or consumed according to its intended use
Food System Lab	Space for experimentation and innovation which covers a wide spectrum of food systems and contexts. The set as a whole represents a substantial amount of spatial, structural, institutional, socio-cultural and economic diversity in food systems.
Food quality	The totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs
Horticulture (Fresh fruits and vegetables)	Fresh produce that is likely to be sold to consumers in an unprocessed or minimally processed form; fresh produce may be sold as intact produce (e.g. berries) or as cut produce (e.g. broccoli).
Inspection body	(1) Third party entity that inspects the product or process according to the standard(s) which it is to be certified against and issues the inspection report to the certification body for approval (certification) and issuing of certificate; (2) Official body or authority that inspects governmental regulations (not private standards). Label Symbol or label that can be put on a

	product indicating that the product or the process to make the product complies with given standards and that this compliance has been certified. Use of label is usually owned by the standard setting body. A label is usually used in communication with the end consumer.
Micro-organism	Includes bacteria, viruses, fungi (yeast and moulds), protozoa (single celled animals) and helminths (worms). Also referred to as microbes.
Pathogen	Micro-organism capable of causing disease or injury in humans, animals or plants
Pest	Refers to any animal of public health importance including, but not limited to, birds, rodents, cockroaches, flies, insect larvae, that may carry pathogens that can contaminate food
Physical hazard	Any foreign object found in a food item, which may cause illness or injury to a person consuming the product. Examples from manufacturing equipment (pieces of metal) or from packaging (glass, plastic) and others such as stones, grass, hair, insects.
Sanitizer	A substance or product used to reduce or eliminate the number of microorganisms without affecting produce quality or safety for the consumer.
Standard body	Governmental or private bodies that establish standards which may be the subject of a certification programme
Traceability	Ability to follow the movement of a food product through specific stages of production, processing and distribution along the supply chain.
Work Package	A work package is a group of related tasks within a project, often thought of as sub-projects within a larger project.

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1. Introduction

Sub-Saharan Africa (SSA) produces a variety of foods and food products at both subsistence and commercial levels. These include local and indigenous foods such as cereals and grains, roots and tubers, fruits and vegetables, livestock, nuts, and forest products (wild fruits, wild edible mushrooms, edible plants, etc). These foods are a resource that is currently underutilized due to various socio-economic restraints and limitations regarding access to information and technologies related to methods of preparation, nutritional value, quality and safety. Better utilization of these foods can potentially improve food and nutrition security, create employment, and contribute to increased income for households as well as to the overall gross domestic product (GDP) of Sub-Saharan countries. The potential of these foods needs to be unlocked to gain the much-needed social, economic, cultural and health benefits they can contribute (FAO, 2002).

Tonnes of edible food are lost and/or wasted every day, with these losses occurring during various stages of the food supply chains (FSC). FAO estimates have put global food loss and waste at one-third of all produced foods (1.3 billion tonnes of edible food) annually in all the food supply chains (Ishangulyyev, Kim and Lee, 2019). One key area for food loss, especially in developing countries, is the post-harvest sequences and their associated activities (Figure 1). As an example, a recent report by World Bank, NRI and FAO (2011) estimates that the value of post-harvest grain losses in Sub-Saharan Africa alone stand at about $4 billion a year. Considering that grains, even though a major source of nutrition, are just one food category, it can be concluded that the economic and social consequences of food loss are significant.

The United Nations agencies estimate that 10% of the global population is susceptible to severe food insecurity. In Africa, the situation is even more dire as the UN estimates that 19.1% of its population is undernourished - that is more 250 million of its people (FAO, IFAD, UNICEF, WFP and WHO, 2020). Food loss and waste are major contributing factors to the global and African food insecurity and their ongoing presence threatens the achievement of the UN Sustainable Development Goal (SDG) No. 2: Zero Hunger by the year 2030 and SDG No. 12: achieving sustainable consumption and production patterns (FAO, IFAD, UNICEF, WFP and WHO, 2020).

When food is lost or wasted, all the resources that were used to produce this food go to waste, including water, land, energy, labour and capital. Moreover, food lost and wasted can end up in landfills, leading to greenhouse gas emissions and contributing to climate change. To remedy this problem, global and local actions are needed from a food systems perspective at all levels including food producers, food supply chain stakeholders, food industries, retailers, and consumers.

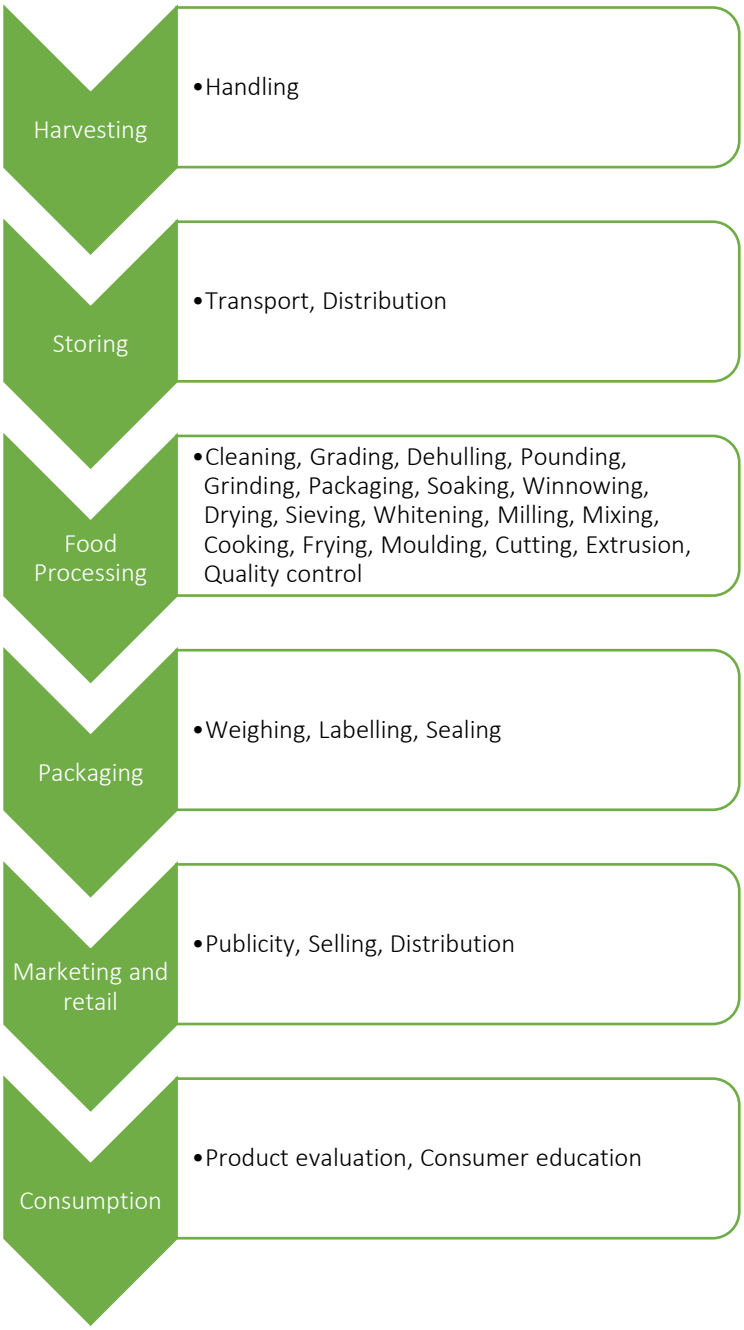

Figure 1. A simplified flow chart of the food value chain and descriptions of common processes that food items go through during their life cycle.

Once harvested, degradation processes start to change the original composition of the crop until it becomes unmarketable and finally inedible. The main causes of reduced shelf life are environmental conditions (temperature and relative humidity), microbial activity, contamination, and physical damages. As the quality of the food product is partly dependent on the quality of the raw materials, it is necessary

to maintain that quality as long as possible. The postharvest shelf life and quality of food products is also very dependent on the type of handling, storage and transport conditions and these should be optimized to further prolong the shelf life of the food. The shelf life of each product can be determined through a combination of sensorial, biochemical, mechanical, and optical measurements.

The HealthyFoodAfrica (HFA) project funded by the European Union (EU) for four (4) years aims to help overcome the different challenges facing agri-food systems in six (6) African countries. The HFA project will raise consumer awareness about healthy nutrition and enhance the capacity of farmers, producers and other food chain actors to deliver diverse, safe, nutritious and affordable foodstuffs. It is undertaken by a consortium of five (5) European Institutions based in Finland, Norway, Italy, Netherlands and Portugal; and six (6) African Institutions based in Benin, Ethiopia, Ghana, Kenya, Uganda and Zambia. The project has five thematic work packages (WP) that holistically address food system challenges: nutrition & consumption, sustainable production, postharvest & food safety, value chain governance and novel products & processes.

The overall objective of Work Package 4 (WP4) within the HFA project is to improve food safety and reduce food loss or waste through the development of post-harvest innovations. WP4 is collaborating with ten (10) localised, context-specific Food System Labs (FSLs) established in the six African countries for experimentation and innovation and will carry out the following activities:

1. Analysis of food safety and food loss challenges.
2. Identification of innovative post-harvest/processing technologies and/or packaging options.
3. Piloting of selected post-harvest and food safety technologies.
4. Co-assessment and validation of innovative technologies.
5. Synthesis of lessons and best practices, which we can adopted by the actors in the supply chain.

In WP4 (Figure 2), the focus is on food safety and food losses or waste of fruits, vegetables, fish and poultry, which are the main food commodities identified by respective FSLs in Ghana, Kenya, Uganda and Zambia. Respiration is one of the important factors of post-harvest handling for fruits and vegetables, while meat and meat products are very susceptible to microbial spoilage and contamination. The handling and storage of meat products are important points for maintaining food quality, as the environmental conditions, especially increased temperature, accelerates the rate of their quality degradation. Therefore, the project will aim to seek improvements for the handling, storage and processing stages of these food products. In addition, the WP will also work on optimizing packaging performance by implementing modelling and optimization studies to choose the best packaging material and functionality for storage and transportation.

The schematic illustration in Figure 2 describes the WP4 approach and working area (in orange) for developing innovative post-harvest technologies to improve food safety and reduce food waste. The food value chain is presented from the perspective of circular economy and sustainable development and,

thus, includes the stage of waste recycling and linking back to production. Food safety (yellow circle) needs to be ensured in all the stages and therefore encloses the entire food chain. The illustration also indicates the difference between food loss (in blue) and food waste (green). WP4 will be mainly concentrating on reducing food losses, which are closely linked to early stages of food chains (from production/harvesting to the retail stage). However, as some of the FSLs' work relates to, for example, open air markets, the studies may also create linkages to food waste. The key development areas of WP4 – post-harvest handling and storage, food processing and distribution – are covered in the area within the black dotted line. This is where many possible technical solutions may be found for handling, storage and transportation. Packaging is an important improvement option in food waste and safety. Principally, food packaging delivers physical, chemical and biological protection by shielding foods from mechanical damage, minimizes compositional changes triggered by environmental influences and provides a barrier to microorganisms, insects, rodents, and other animals. The choice of packaging is a complex process that depends on the product and its supply chain. Factors that need be considered include product quality, physical and chemical characteristics, transport and lengths, product contamination, stocking, stackability, material selection, packaging cost, etc. WP4 has expertise that can be utilized to help the FSLs in their projects to choose the most adapted solution to their stakeholders' needs.

Packaging process and material selection are one aspect of these technical solutions. It is very important that the packaging is tailored for the specific food product and considers how the packaging is recycled. Good facilitation of the packaging design and selection process between the supply chain members can lead to adoption of innovations and improve food chain sustainability (García-Arca, Garrido, and Prado-Prado 2017). The packaging materials (glass, metal, cardboard or plastic) and processes at various stages need to be evaluated from the viewpoint of technical performance, food contact material approval as well as availability and cost. As an example of successful evaluation and collaboration, reusable containers have been introduced for agricultural-food supply chains to decrease food loss and improve food safety (Singh et al. 2016). A multitude of active and intelligent packaging solutions exist that ensure food safety and efficient logistics, but their practical implementation to consumer markets have remained limited due to socio-economic challenges (Tiekstra et al. 2021). Overall food supply chains are notoriously complex and rely on good communication between actors to innovate and achieve sustainability.WP4 will contribute also toward human capacity building through training and information sharing between project partners and FSLs in the food chain.

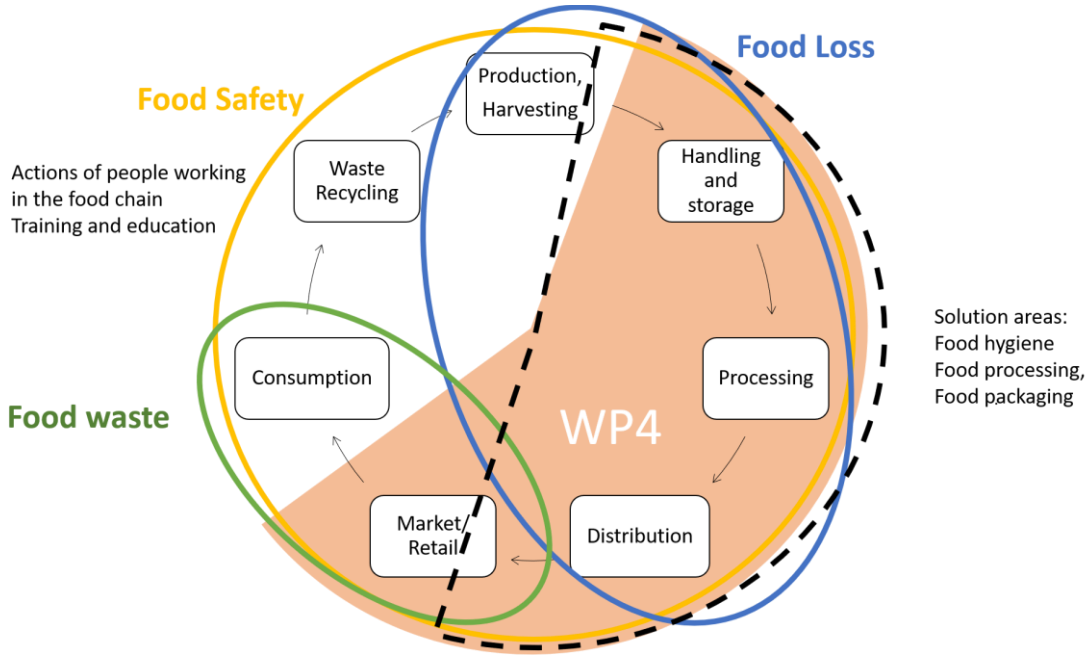

Figure 2. Work Package 4 (WP4) work (orange) in the circular food system. The circles (yellow for food safety, blue for food loss and green for food waste) represent the relationships of the central concepts in the food chain. The area of potential (technical) solutions is highlighted with the black dotted line.

Since food moves from farms to consumers via supply chains composed of multiple actors, food safety hazards (physical, chemical, and biological) can enter the food chain at any stage from farm to fork. Food safety challenges seem to be predominant across value chains. These challenges include safety of foods produced by the farmers, food sold directly to the public (street vended foods), and imported foods. Food safety hazards are a serious public health concern world-wide with far reaching consequences that include outbreaks of food borne diseases, medical costs, loss of lives, long term debilitating effects and loss of productivity. The problem of food borne diseases is further compounded by the emergence of antimicrobial resistance. In addition to public health concerns, access of food commodities to both local and export markets may be limited due to the failure to meet food trade regulations. Adequate control through food safety management systems integrating the prerequisite programs (PRPs) and principles of Hazard Analysis and Critical Control Point (HACCP) application steps is thus essential. Ensuring food safety is vitally important especially to small and medium enterprises (SMEs), particularly those in the horticulture, aquaculture, and poultry sectors as they are constrained by limited resources and lack of expertise concerning food safety standards and management systems.

According to FAO and WHO (2003) hazards emerge from:

1. the design of the food and agricultural systems, such as intensive livestock operations and the globalisation of distribution and processing

2. technologies and their by-products, such as the use of pesticides, heavy metals, growth promoters, antibiotics, fertilisers and genetically engineered crops and foods
3. technologies introduced to solve other food safety and quality problems, including additives and irradiation
4. adulteration (intentional or unintentional)
5. new approaches to food as health delivery agents, functional foods and edible vaccines
6. poor hygiene and sanitation and other food safety risks

Therefore, in WP4, we will identify the risks and possibilities of hazards in food chain from harvesting to consumption. Food safety program for Good Handling Practices and Good Hygienic Practices will be discussed and adopted for target commodity.

2. Scope of discussion paper

This paper discusses food loss and food safety challenges in post-harvest (WP4) and reviews current technologies used in the food supply chains of the Food Systems Labs (FSL) in the HFA project. Largely based on literature and primary data from FSLs, the paper identifies food safety and food loss challenges and gaps, and proposes solutions that can be evaluated as possible interventions.

3. FSLs within WP4

WP4 collaborates with five FSLs that are located in Nairobi, Fort Portal, Accra, Chongwe and Lusaka. Each FSL's focus, challenges and contributions are summarized in Table 1.

Table 1. FSL focus, challenges and contributions (based on project Grant Agreement)

FSL	***FSL focus and WP links***	***Challenges and emerging priorities of FSL***	***Specific contribution toproject goals***
FSL-Nairobi	**FSL-Na | Nairobi, Kenya, Korogocho & Viwandani settlement,** Lead: APHRC *Boosting food security, safety and nutrition of slum dwellers* **WPs 2, 3, 4, 5 & 7**	Poor food security and lack in livelihood opportuni ties in high-density areas. FSL-Na will work with women and street vendors to promote urban agriculture using modern but affordable technologies, improve food hygiene and reduce food losses.	Empowering women & improving the sustainability, efficiency & safety of agrifood systems in densely populated areas and slums.
FSL-FP	**FSL-FP | Fort Portal, Kabarole District, W. Uganda,** Lead: Hivos *Alleviating child malnutrition and restoring agricultural productivity* **WPs 2, 3, 4 & 7**	Child stunting due to monotonous diets. A holistic approach promoting awareness of healthy, nutritious diets, as well as sustainable agricultural practices will be promoted. Actions include policy-dialogue, but also innovative radio drama.	Methodologies for holistic approaches to target interlinked food system challenges. Tailored radio drama campaigns.
FSL-AC	**FSL-Ac | Accra, Greater Accra Region, S. Ghana,** Lead: CSIR *Enhancing use of fish as part of a healthy diet & agri-food chain development* **WPs 2, 3, 6 & 7**	Food safety and efficiency in fish production in and around Accra. In order to provide healthy protein rich foods to improve local diets, new processing and post-harvest options will be developed and evaluated.	A range of new processing methods for fish, including smoking, rapid freezing, vacuum packing, extrusion cooking.
FSL-Lu	**FSL-Lu | Lusaka, Lusaka Province, S.E. Zambia,** Lead: Hivos *Capacity building, formal recognition & participation of food traders and vendors* **WPs 2, 4, 5 & 7**	Most urban consumers depend on food vendors for accessing healthy and safe food. Enhancing the role of the informal sector and boosting local economic activity in collaboration with local	Models for linking the formal and informal food sector to enhance access to nutritious food for city dwellers

		authorities. Training on food safety.	
FSL-Ch	**FSL-Ch | Chongwe District, Lusaka Province, S.E. Zambia,** Lead: Hivos *Fostering vegetable production & related chains for a sustainable food system that is supplying Lusaka.* ***W*Ps 2, 3, 4, 5 & 7**	Challenges faced by vegetable producers in accessing markets. Training of farmers on sustainable farming practices. Improving vegetable chains through a participatory, multi-actor approach that empowers farmers to access markets.	New city-region food strategies, highlighting promising value-chain options; entrepreneurship support, and agribusiness models.

4. Food Loss and Waste

4.1 Definition of Food Loss and Waste

There is a lack of consensus on the definition of food loss and waste. Food loss and waste have been defined on many dimensions: quantitative and qualitative loss, stages in the food supply chain at which the loss occurs, and regional differences observed. On a quantitative and qualitative loss dimension, food loss has been defined as 'the decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption', while food waste has been defined as 'food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil' (FAO, 2018). Food loss is synonymous to postharvest loss (Delloite & Touche, 2020). On the food supply chain dimension, food losses are reported to occur between the harvest or slaughter and processing stage (Figure 4), although some define food loss as being from harvest to the retailing stage of the supply chain (Delloite & Touche, 2020). Food waste occurs at the retail and consumption stages of the supply chain (Ishangulyyev, Kim and Lee, 2019).

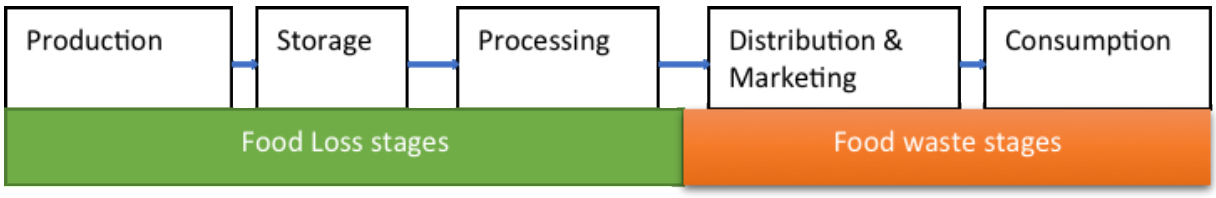

Figure 4. Definition of the food loss and food waste on the supply chain. Adapted from (Ishangulyyev, Kim and Lee, 2019).

Although food loss is said to occur in both developed and developing countries to the same extent, food waste mostly occurs in developed countries (FAO, 2018; Delloite & Touche, 2020). For example the food loss in Sub-Saharan Africa has been estimated to represent 95% of the total food lost and wasted, combined (Table 2).This discussion paper focuses on food loss it is a more critical challenge faced by developing countries than food waste. The food supply chain stages of focus in this paper for food loss are from harvest to retail as defined by Delloite & Touche (2020) and the term "food loss" will be used interchangeably with "post-harvest loss". The FAO method of food loss assessment categorizes food loss into three types, namely, physical, physiological and pathological losses (FAO and Save Food, 2014).

Table 2. Differences in food loss and food waste in developing and developed countries.

	FOOD LOSS (%)	**FOOD WASTE (%)**
Sub-Saharan Africa	95	5
South and South East Asia	87	13
Latin America	72	28
North Africa, West and Central Asia	66	34
Industrialized Asia	54	46
Europe	49	51
North America and Oceania	39	61

Delloite & Touche (2020)

4.2 Extent of Food Losses

FAO estimates have put global food loss and waste at one-third of all produced foods (1.3 billion tons of edible food) annually in all food supply chains (Ishangulyyev, Kim and Lee, 2019). The extent of food or post-harvest losses in Sub-Saharan Africa has been found to be different according to the food commodity and the stage in the supply chain. Fruits and vegetables have been found to have the highest loss estimates at more than 50% compared to other food commodities, which range from 19 to 44% (Table 3).

Table 3. Food losses or wastage along the supply chain in Sub-Saharan Africa

STAGE IN SUPPLY CHAIN	FOOD LOSSES OR WASTAGE (%)			
	FRUITS & VEGATBLES	**ROOTS & TUBES**	**OILSEEDS & PULSES**	**CEREAL & GRAINS**
Production	10	14	12	6
Handling & storage	8	15	7	8
Distribution	20	11	6	3
Processing	10	3	1	2
Consumption	3	1	1	1
Overall lost or wasted	62	44	28	19
Annual tonnage lost or wasted (million)	54	113	7	26

Delloite & Touche (2020)

4.3 Causes of Food Losses

FAO has developed a cause finding diagram which can be used to facilitate identification of the symptoms, alternative causes, real causes and underlying reasons to the problem of food loss (Figure 5) (FAO and Save Food, 2014).

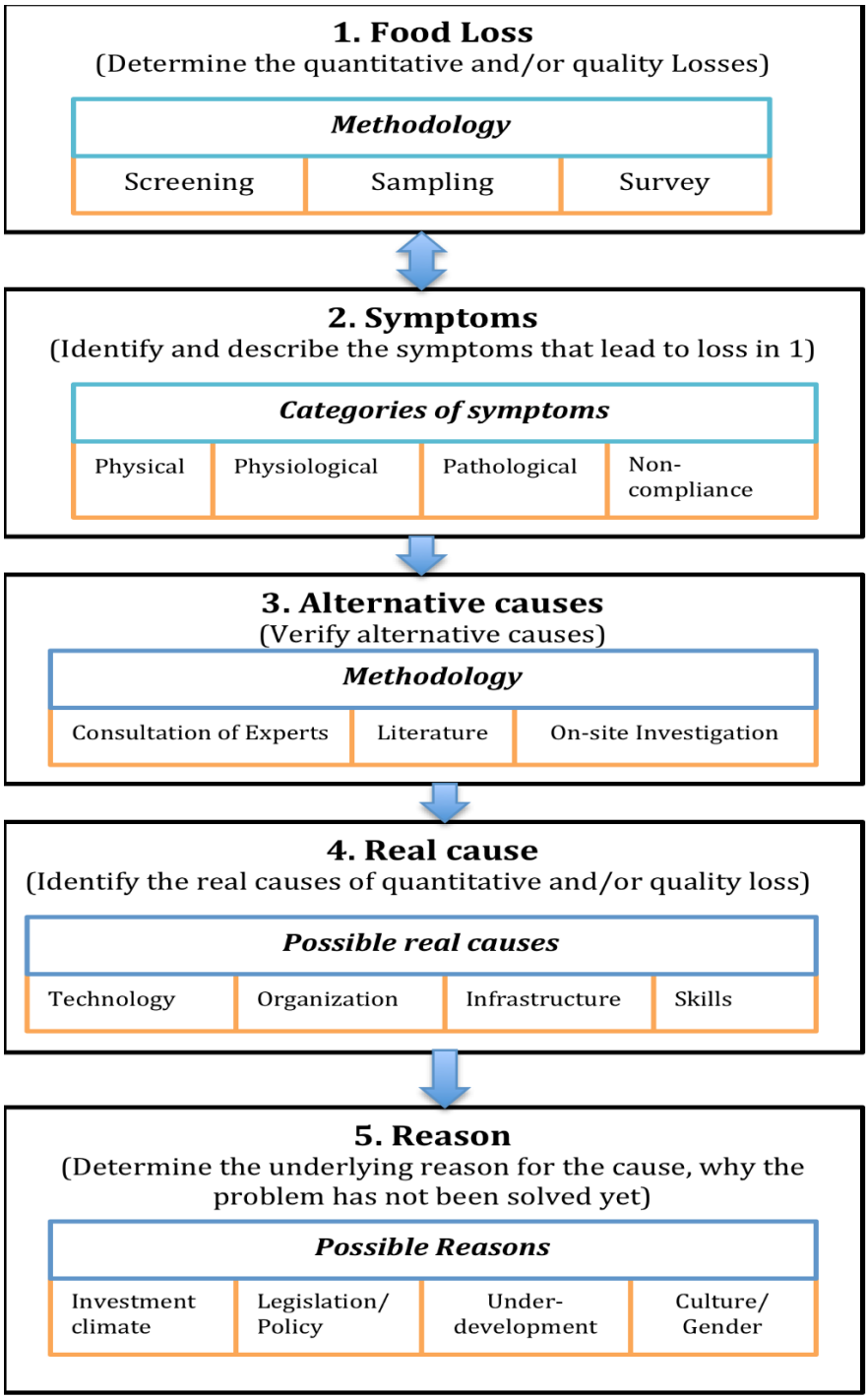

Figure 5. Cause finding diagram. Adapted from FAO and Save Food (2014).

Generally, the causes of food loss have been associated with inefficiencies in the food supply chain including inadequate technology, poor infrastructure, poor access to markets, and

inadequate knowledge and management skills of the actors along the supply chains, from harvesting to retail (FAO, 2018). These data are in line with Information obtained from FSL-Chongwe. Among others, respondents reported limited knowledge on food preservation techniques as well as lack of specialized transportation from farm to point of use as one of the main causes of food loss or waste (See Appendix section 9.2). A more detailed analysis of the causes of food loss at each stage of the food supply chain reveals that they are dependent on the stage in the supply chain and on the commodity.

Table 4 summarizes some of the possible causes of food losses at each stage in the food supply chain. At the production stage, access to high quality seed varieties, pesticides, fertilizers, farmer training programmes, extension services, metrological services and finances are important factors to food loss. Overproduction of crops has led to higher losses in developing countries because of low capacity for storage and effect on pricing in subsequent stages of the supply chains.

Food loss at harvest is affected by the harvesting time, harvesting methods and availability of labor. The transportation from farm to storage facilities in developing countries affects food loss due to poor transportation modes and limited packaging types for transportation. On-farm storage stage losses are due to limited storage facilities and improper use of storage chemicals. Food loss during packaging of agricultural products at farm level *enroute* to processing and retail market is mostly determined by the mode and type of packaging.

Table 4 Causes of food loss in food supply chains

Stage in the FSC	Possible Cause of Food Loss
Production[1]	Infrastructure limitations, over production, pesticide and fertilizers, choice variety
Harvesting[1]	Harvesting time, harvesting method, infrastructure limitations, quality standards
Transportation from farm to storage facilities	Mode of transport, type of packaging, loading and off-loading practices
On farm storage	Storage infrastructure limitations, degradation and spillage, characteristics of the variety, improper use of storage chemicals
On-farm packaging	Type of packaging
Processing[1]	Unavoidable losses, technical inefficiencies and malefactions, legislation restrictive, overproduction, storage conditions
Packaging of processed products	Packaging mode, packaging materials, packaging knowledge, packaging availability, packaging standards
Distribution[1]	Inappropriate conveyance conditions (temperature, humidity etc), contamination of transportation, transportation facilities, roads & distribution vessels
Marketing (Retailing)[1]	Business rules, packaging, commercial conditions, consumer reference

[1]Ishangulyyev, Kim and Lee, 2019

Food losses at the processing stage of the food supply chain depends on the level of establishment, that is, whether we are dealing with small-to-medium (SMEs) or large-scale enterprises. The level of processing, primary (minimal) or secondary processing, also determines the amount of food losses. At the processing stage food losses are due to unavoidable losses such as weight loss during processing, technical inefficiencies and malfunctions (e.g. quality defects during processing), legislative restrictions (e.g. discriminative quality standards for simple properties like appearance), overproduction of products (e.g. very short shelf life) and storage conditions (e.g. the ability to maintain a cold chain).

Food losses at the stage of packaging processed products are limited by the packaging mode such as individual product versus bulk packaging, packaging material (plastic, paper, metal etc), packaging knowledge of the processor, packaging options and availability to the processor, and the existence of packaging standards and their enforceability. Data from marketeers in FSL-Lusaka (see section 9.3) are in tandem with findings of Ishangulyyev et al (2019).

The food losses at the distribution stage to retail markets are determined by poor conveyance conditions such as temperature, contamination of transport vessels due to co-transportation of raw materials and finished products, poor transportation facilities such as use of non-refrigerated trucks and poor road infrastructure, especially in the rural areas.

4.4 Food Losses in WP4 FSLs

This section focuses on available food loss data, specific important causes and possible interventions required to mitigate food losses in the food supply chains (FSC) identified in the HealthyFoodAfrica (HFA) project and studied in the Food System Labs (FSLs). The selected FSLs and their selected food supply chains are as shown in Table 5. The general FSC categorizations considered are fruits, vegetables, fish, and poultry.

Table 5. Selected food supply chains in FSLs in HFA

No.	Food System Lab	Country	Selected Food Supply Chain
1	FSL-Chongwe	Zambia	Vegetables (African Leafy Vegetables)
2	FSL-Lusaka	Zambia	Vegetables
3	FSL-Accra	Ghana	Fish (Tilapia and cat fish)
4	FSL-Tamale	Ghana	Fruits
5	FSL-Nairobi	Kenya	Vegetables, Poultry, Rabbits
6	FSL-Kisumu	Kenya	Fish, Vegetables (African Leafy Vegetables)
7	FSL-Fortportal	Uganda	Vegetables
8	FSL-Bahir Dar	Ethopia	Fish, Vegetables
9	FSL-Rwamwanja	Uganda	Maize
10	FSL-Cotono	Benin	Vegetables

4.4.1 Losses in Fruits & Vegetable Supply Chains

Vegetables in Sub-Saharan Africa play very important roles in food security and nutrition, as they are one of the major sources of minerals, vitamins, and fibre for all ages. They are also a source of income and highly contribute to livelihoods. Vegetables are generally categorized into exotic and indigenous, or traditional, vegetables. The majority of the traditional vegetables are the so-called African Leafy Vegetables (ALV) and they include amaranth, sweet potato leaves, pumpkin leaves, cowpea leaves, bean leaves, cassava leaves, rosella leaves, cat-whiskers, to mention a few.

Vegetables have been reported to have high food losses. However, food loss data, especially for traditional vegetables in Africa is scarce and calls for the establishment of baselines in the FSLs. Table 6 gives an indication of the extent of post-harvest losses of vegetables in selected African countries in the HFA project. Overall, food losses in these vegetable FSCs are high for all loss types, with mechanical damage being higher than loss through physical and decay.

Table 6. Postharvest losses of vegetables in African countries

COUNTRY	COMMODITY	METHOD	FSC STAGE	PHYISCAL LOSS (% DISCARDED)	QUALITY LOSS (% MECHANICAL DAMAGE)	QUALITY LOSS (% DECAY)	OVERALL LOSS (%)
Ghana[1]	Tomatoes	Sampling, Interview	F, W, R	21.5 - 25.1	10.5 - 33.5	11 - 17	20
	Cabbage	Sampling	F, W, R	6.5 - 28.1	32 - 54	5 - 13	
	Egg plant	Sampling	F, W, R	11.3 – 16.2	9.5 - 22	0 - 2.8	
	Okra	Sampling	F, W, R	2.3 - 16.6	4.5 - 28	0 – 8.5	
Benin[1]	Tomatoes	Sampling	F, W, R	23 – 31.2	27.5 – 31.2	21.2 – 27.5	
	Tomatoes	Sampling					28[a];40[b]
	Peppers	Sampling	F, W, R	5.9 - 11	7 - 15	8 - 24	
	Amaranths	Sampling	F, W, R	17.3	34.5 – 89.5	47	
Ethiopia[2]	Tomatoes	Interviews					19.4
	Melon	Interviews					16.7
	Onion	Interviews					10.7
	Potato	Interviews					6.0
	Sweet potato	Interviews					2.9
	Beet root	Interviews					2.7
Zambia[3]	Tomato	Sampling	F, T		5.8 – 8.2	42.3 - 65.3[c]	

F=Farm; W=Wholesale; R=Retail; T=Transport; [a]Volume; [b]Economic value; [c]Physiologically damaged; [1]Katinoja and Kader (2015); [2]Tesfay and Teferi (2017); [3]Shindano et al, (2018)

There is low consumption of fruit in Sub-Saharan Africa, although they are an important source of minerals, vitamin and fibre. Fruits also have great potential to uplift the livelihoods of the people through entrepreneurship and there is high potential for production of tropical fruits in most Sub-Saharan African countries, where some of the fruit trees grow naturally and un-attended. However, Table 7 shows that there are high losses of the tropical fruits in the supply chain, especially seasonal losses which have been reported to be as high as 70%. Similar to vegetables, the food loss data for fruits is scarce and further calls for the establishment of baselines in the FSLs.

Table 7. Postharvest losses of fruits in African countries

COUNTRY	COMMODITY	METHOD	FSC STAGE	PHYISCAL LOSS (% DISCARDED)	QUALITY LOSS (% MECHANICAL DAMAGE)	QUALITY LOSS (% DECAY)	OVERALL LOSS (%)
Ghana[1]	Mangoes	Sampling	F, W, R	6 – 10.4	2.3 - 8	0.4 - 2.5	
Benin[1]	Oranges	Sampling	F, W, R	10 – 11.6	15 - 51	5 - 33	
	Mangoes	Sampling					17[a]; 70[b]
Ethiopia[2]	Guava	Interviews					49.2
	Pineapple	Interviews					28.2
	Mangoes	Interviews					26.3
	Mandarin	Interviews					17.4
	Papaya	Interviews					11.5
	Orange	Interviews					9.0

F=Farm; W=Wholesale; R=Retail; T=Transport;[a]Early April; [b]Mid June – fruit flies; [1]Katinoja and Kader (2015); [2]Tesfay and Teferi (2017)

The causes of loss in the fruits and vegetable supply chains are numerous; the main ones are physical-chemical damages and biological processes. The physical-chemical damages can be caused by mechanical risks (e.g. bruising) or ambient risks (e.g. high or low temperatures). Biological processes involve respiration, development and senescence, diseases and other pathological factors. Further identified causes include the inability to determine the best maturity stage to harvest, keeping the produce in the field under sunny conditions for a long time, use of inappropriate packaging during transportation and retailing, weather conditions, initial disease incidence in the field, pests, rough handling, poor trading facilities and lack of sorting (Katinoja and Kader, 2015; Shindano et al., 2018).

4.4.2 Losses in Fish Supply Chains

Fish is among the important sectors in Sub-Saharan Africa as it is one of the major sources of protein. Fish is also highly traded both at commercial and subsistence levels, thereby contributing to the livelihoods of the majority populations. However, the fish supply chains in Sub-Saharan Africa can be quite complex and face a number of limitations contributing to fish losses, including the fact that fish is highly perishable. Limited data in Table 8 shows that physical and quality losses can be as high as 50% in fish supply chains. Fish can be processed into various products and fish loss therefore depends on the product type.

Table 8. Postharvest losses of fish in African countries

COUNTRY	TYPE	METHOD	FSC STAGE	PHYISCAL LOSS (%)	QUALITY LOSS (%)
Zambia[1]	Dry fish	Interviews*	Fishing node	0 – 50 (2.03)	
			Processing	0 – 50 (7.42)	
			Trading	0 – 40 (2.87)	
Ghana[2]	Smoked fish	DNA		3-17	37.5
		DNA		16-20	30.7
Kenya[2]	Sardine	DNA	Before processing	0 – 7.5	1.5 -18.9
		DNA		1 - 5	28
	Fresh Tilapia		Trading	l	27
Uganda[2]	Sardines	DNA		26-40	2 - 5
	Fresh Tilapia	DNA			2.5 – 5.2

*****EFLAM, IFLAM, QLAM, methods; the value in brackets is the mean; DNA – Data Not Available; [1]Kefi et al, (2017); [2]Akande and Diei-Ouadi, (2010)

Fresh fish loss may be caused by biochemical and microbiological spoilage due to reactions triggered after the death of the fish. These may be influenced by various factors such as the time between death of the fish and final use or consumption, temperature abuse and poor handling practices. Other causes of fish losses include breakages, pest infestation and spoilage for dried fish (Kefi et al, 2017). The lack of ice, poor icing practices, poorly designed-insulated containers and poor fish handling in fish vessels have been cited as causes of losses in fresh fish. Causes of losses in fish during drying and smoking include lack of drying racks and poorly designed smoking ovens. Inappropriate packaging materials such as polypropylene sacks and traditional fish baskets, as opposed to rigid packaging, during transportation of dried fish have also been given as reasons for fish losses in the supply chains (Akande and Diei-Ouadi, 2010). The FSLs have also identified market dynamics, especially fluctuations in supply and demand of fish and fish products, affecting price and therefore income, being one of the major factors to consider in the loss of fish, especially fresh fish.

4.4.3 Losses in Poultry Supply Chains

Poultry is defined as domesticated birds that include chickens, turkeys, ducks, geese and guinea fowl, for their meat and eggs. Among poultry, chicken breeds account for 63% of the world's genetic diversity and they are the most consumed of all poultry (Nkukwana, 2018).

Globally, chicken meat production has grown by about 42% in the last decade from ~80 million metric tons to more than 109 million metric tons, while egg production has grown by 2.7% from 60 to 80 million metric tons between 2007 and 2017. Sub-Saharan Africa's chicken meat production grew by 46% from 2.1 to 3.1 metric tons and egg production by 2.2% in about the same period. This could be attributed to a large extent to the shift from free range to intensive poultry production systems. In some African countries, poultry and fish are taking market shares away from red meat, due to an expansion of fast foods, consumer preferences, competitiveness and concerns about the safety of red meats (Shaw, Nielson and Rose, 2019). The chicken meat supply chain in Africa can be split into two types of channels: the live chicken channels and slaughtered or dressed channels (supplying dressed whole chicken or chicken pieces). There is also a growing channel for secondary processed chicken, such as smoked chicken and chicken sausages.

The challenges in the FSLs post-mortem supply chain include:

1. lack of data on post-mortem losses of chicken
2. poor slaughtering facilities, especially for small poultry processes
3. lack of appropriate and affordable processing equipment
4. lack of energy to support processing activities, especially to maintain the cold chain at the slaughter and transportation stages, particularly for electricity off-grid farms
5. poor market systems for free-range chickens for small scale poultry farmers

Some solutions identified for the Sub-Saharan Africa chicken post-mortem supply chains include mobile slaughtering, packaging and cold storage facilities used for processing chickens at small poultry farmers. However, it has not been ascertained whether this type of solution is economically viable and scalable (Shaw, Nielson and Rose, 2019).

4.5 Consequences (Impact) of post-harvest losses

The impacts of food losses, especially for developing countries, are many and cannot be over-emphasized. Overall, food losses and wastage may be categorized into economic and environmental impacts. Economic impacts include product loss, reduction in product lifespan, and decreased quality. They are amplified through reduced availability of food and reduced income for the livelihoods of the poor, thereby putting populations at a higher risk of food insecurity and poor nutrition. Food loss has an impact on the prices of commodities because supply chain actors increase prices to compensate for the food lost in the chain, thereby also leading to unsustainable food systems. Environmental impacts include resource loss through depleting natural resources and the destruction of the environment through increasing greenhouse gas emissions. The food loss factor will contribute to developing countries failing to attain the Sustainable Development Goal (SDG) No. 2: Zero Hunger by the year 2030 and SDG No. 12: achieving sustainable consumption and production patterns.

4.6 Food loss assessment

There are various approaches that have been used to assess food loss and determine the extent of food loss in different food supply chains. The most commonly used methods include soliciting estimates from stakeholder-value chain actors, surveys based on recall methods, and objective measurements by sampling at supply chain stages (Ishangulyyev, Kim and Lee, 2019). In fish loss assessment, Exploratory Fish Loss Assessment (EFLAM) (previously known as Informal Fish Loss Assessment method, IFLAM) and Quantitative Loss Assessment method (QLAM) have been used (Kefi et al, 2017).

It is important to note that different loss assessment methods, loss indicator terminologies and segmentation of the points or stages of the FSCs are used. This makes it difficult to compare data from different sources. To mitigate this issue, we recommend that the HFA project uses a FAO recommended methodology which integrates four methods, called the 4-S method, and involves screening, survey, sampling and synthesis (FAO and Save Food, 2014). This integrated method is as follows:

1. Preliminary Screening of Food Losses ('Screening'): Here food loss assessment is conducted by the use of secondary data, documentation and reports, and expert consultations;

2. Survey Food Loss Assessment ('Survey'): This method is based on recall through a questionnaire exercise differentiated for actors along the food supply chain. This could be coupled with sampling at selected stages in the food supply chain and observational methods;

3. Load Tracking and Sampling Assessment ('Sampling'): In this method, the food loss assessor tracks the movement of the food along the stages of the supply chain and samples at those stages to determine the extent of losses in the supply chain; and

4. Solution Finding ('Synthesis'): Here, using the data from the above three methods, the food loss assessor determines the factors leading to the food loss along the supply chain and develops the interventions to mitigate the losses.

The 4-S method advocates the determination of Critical Loss Points (CLP) in the food supply chain. The CLP are defined as the points in the FSC where food losses have the highest magnitude, the highest impact on food security, and the highest effect on the economic result of the FSC. The CLP require that we have consensus on threshold food loss quantity criteria.

4.7 Interventions in Fruit & Vegetable, Fish and Poultry Supply Chains

This section catalogues some of the potential interventions and those that have been used to mitigate losses in fruit and vegetable, fish, and poultry in the recent past. High level interventions on food loss (Ishangulyyev, Kim and Lee, 2019) include governments investments in infrastructure, improving extension services, improving market access, supply chain actor awareness and education, access to financing, tax incentives, improving governance in the supply chains, development and enforcement of standards, among others.

Delloite & Touche (2020) have categorized interventions to mitigate food loss into two categories, product and process interventions. Product interventions are technologies that depend on manipulating the product and environmental properties to minimize food loss, and these can be storage and handling solutions or value addition solutions. Process interventions are food supply chain governance innovations to maximize the supply chain efficiency, some of which have been identified in the paragraph above. Examples of the two interventions are illustrated in Table 9.

Table 9. Product and process interventions

	POSTHARVEST LOSS SOLUTION	**SOLUTION DESCRIPTION**
Product Solution: Storage and handling	Gum Arabic coating	Edible coating manufactured from acada tree sap used to coat certain fruits and vegetables to delaying ripening
	Zero fly bags	Insecticide-incorporated storage bags for crops capable of preventing pest infestations
	Liquid air refrigeration: Cold storage	Cooling air to very low temperatures for cold storage and transport of perishables; technology still to be piloted in an African context
	Warehouse Receipt Systems	Secure storage combined with deposit system and credit mechanism; difficult to implement in contexts where financial systems are not mature
	Heavy moulded plastic containers	Durable, protective, and cost-effective plastic containers with the ability to prevent crop damage during storage and transportation
	Low energy cooling	Micro-controller that allows conventional window air conditioning units to operate at colder temperature at lower costs for cold storage
Process Solutions: Value addition	Mobile/Solar drying	Diesel-powered or solar driers used to reduce moisture in crops, thereby extending shelf life and preserving nutritional integrity
Process Solutions:	Collection centres	Aggregation points that link farmers to buyers, primarily offering grading, packing and storage services

Procurement channels	Contract farming	Contractual agreement where a primary off-taker provides a farmer with agricultural inputs and training to produce contractually specified crops
	Direct sourcing	Procurement channel where farmers establish contractual agreements directly with buyers; limited inputs and technical assistance provided
	Supply chain technology platforms	Use of technology platforms to connect farmers and potential buyers

Delloite & Touche (2020)

5. Food safety in post-harvest

5.1 Introduction

The typical causes and sources of food safety problems during production and post-harvest handling fall into three major categories: physical, chemical, and microbiological hazards. Physical hazards may become imbedded in agricultural produce during production handling or storage and include things such as fasteners (staples, nails, screws, bolts), pieces of glass and wood splinters. Chemical hazards may contaminate produce during production handling or storage and include pesticides, fungicides, herbicides, rodenticides, machine lubricants from forklifts or packing line equipment, heavy metals (lead, mercury, arsenic), industrial toxins, compounds used to clean and sanitize equipment. Human Pathogens to a large extent constitute microbiological hazards and there are four main types of human pathogens associated with fresh produce: soil associated pathogenic bacteria (*Clostridium botulinum*, *Listeria monocytogenes*), faecal associated pathogenic bacteria (*Salmonella* spp., *Shigella* spp., *E. coli* O157:H7 and others), pathogenic parasites (*Cryptosporidium*, *Cyclospora*), pathogenic viruses (Hepatitis, Enterovirus), etc.

5.2 Food safety in FSLs collaborating with WP4

This section discusses food safety issues of selected food commodities in selected FSLs.

5.2.1 Food safety in horticulture (fruits and vegetables)

The horticultural sector plays an important role in human nutrition, health, and boosting the economy, particularly through employment creation and income generation in Sub-Saharan countries. The full potential of this sector is not fully exploited due to food safety challenges that occur at pre-harvest and post-harvest stages. At the pre-harvest stage there are several routes through which fruits and vegetables become contaminated with food hazards, including pesticides, fertilizers and environmental contaminants (heavy metals and other pollutants). According to Chen and Chen (2017), chemical pesticides, fertilizers and environmental contaminants are important concerns for consumers. The issue of pesticides has been prominent from the interactions with FSLs, especially FSL-Chongwe (see in section 9.2). It is therefore reasonable that these issues should be adequately addressed during the implementation of project activities.

During post-harvest activities (harvesting, handling, storage, processing, packaging, transportation, and marketing), pathological, physiological, and physical damage may predispose fruits and vegetables to microbiological hazards. Chen and Chen (2017) suggest that post-harvest operations create surfaces upon which enteric pathogens can attach more easily and the often cut surfaces of produce also release large amounts of nutrients that are readily utilised by spoilage and pathogenic micro-organisms. Spoilage organisms include bacteria (*Pseudomonas* spp, *Shewanella* spp, *Acinetobacter*), yeast (*Candida* spp, *Saccharomyces* spp, *Torulopsis* Spp) and fungi (*Penicillium* spp, *Fusarium* spp, *Aspergillus* spp, *Geotrichum* spp, *Cladosporium* spp), while pathogenic micro-organisms include *Escherichia coli* O157:H7, *Salmonella* species, *Shigella* species, *Listeria monocytogenes*, and *Cryptosporidium*. Other hazards such as antimicrobial agents (disinfectants/sanitizers), colouring substances and preservatives may occur during processing and packaging operations. These hazards may persist along the value chain until they reach the consumer and cause adverse health effects. Hazards associated with post-harvest activities are relevant to FSLs where fruits and vegetables are sold through street vending and open markets. The farm produce sold includes tomatoes, onions, peppers, cabbages, tubers, leafy vegetables, and various squashes.

5.2.2 Food safety in fish

The fishery sector plays an important role in trade, food and nutrition security, employment and rural development for countries in the Sub-Saharan region. Fisheries

can be broadly classified into three (3) categories: inland capture fisheries, inland aquaculture and marine fisheries. Current trends show that inland capture fisheries represent the most important source of fish supply in many countries in Sub-Saharan Africa. Due to increased demand for fish and fish products in the region, governments of respective countries in SSA are promoting inland aquaculture. This promotion may be partly attributed to fish being a cheaper source of protein but may also be due to this sector being viewed by these governments as one with potential for employment creation especially for women and youth. According to FAO (2020), aquaculture is defined as the farming of aquatic organisms including fish, mollusks, crustaceans, and aquatic plants.

The promotion of inland aquaculture in the region has generated interest among several stakeholders. In Zambia, for instance, a number of aquaculture businesses have been set up and are fully operational. The sector has attracted players from varied backgrounds, including some that do not have adequate infrastructure, resources and relevant skills to efficiently run these businesses. Besides the above-mentioned limitations for individual players, institutional capacities to coordinate and regulate the sector are not well established. The above scenario is therefore likely to pose a challenge to the success of these businesses, more so with regards to the production of fish and fish products that are safe for human consumption. Hazards and risks, which may adversely affect human health, are inherent in all human food production including aquaculture. Similarly, the FAO (2016), country-specific data on fisheries and aquaculture for Ghana highlighted both institutional and enterprise level challenges that include:

- Inadequate enforcement of fisheries and aquaculture regulations
- Poor coordination among multiple stakeholders
- Inadequate control on fish farming zones
- Difficulties with access to land
- Poor control of discharges into water bodies
- Poor access to financial credits (especially small and medium-scale farmers)
- High cost of supplementary fish feed
- High cost and shortages of quality fish seed
- Lack of technical expertise and experience
- Unavailability of skilled workforce.

The food safety hazards associated with fish and fish products are mainly biological and chemical in nature. Biological hazards are mostly bacteria, parasites, fungi and viruses, to a lesser extent in tropical environments. Chemical hazards are pollutants

(heavy metals), mycotoxins from contaminated feed, drug residues, pesticides from water run-off, cleaning agents, disinfectants and sanitizers. Within the framework of this project, FSL-Accra highlighted some of these food safety challenges. It is therefore important that these challenges are contextualized during the implementation of project activities.

5.2.3 Food safety in poultry

Poultry is one of the fastest growing agricultural sub-sectors that play a vital role in improving livelihoods, food and nutrition security and poverty alleviation in most developing countries. The sector provides an affordable dietary product for consumers and profit for the producer (Rodic and Peric, 2011). According to OECD/FAO, (2016) chickens are the most commonly farmed species worldwide, with over 90 billion tons of chicken meat produced annually.

In Sub-Saharan Africa, small and medium scale producers that usually have inadequate resources and skills in poultry production dominate this sector. Manyi-Loh, C., et al. (2018)highlight several food safety challenges mainly attributed to poor rearing and hygiene practices e.g. inconsistent administration of antibiotics when treating infected poultry, overcrowding due to poor housing, contaminated feed and drinking water, poor sanitation and hygiene practices during slaughter. In addition, poultry and poultry products are usually sold directly to consumers with no monitoring system to ensure safety. Farmers slaughter their birds without adequate slaughter facilities as it is expensive to use established slaughter abattoirs. Some of these challenges were also highlighted by FSL-Nairobi during HFA project consortium meeting held on 3rd to 4th of December, 2020.

Due to the above raised concerns, safety of poultry continues to be a major concern for consumers. Several food safety hazards affecting the poultry industry have been documented previously. According to Wahyono and Utami (2018) food safety hazards associated with poultry are mainly two categories: chemical hazards (e.g. contaminants such as toxic chemicals, unsafe levels of cleaning and sanitizing chemicals,) and biological hazards (e.g. organisms such as bacteria, viruses, fungi, and parasites). Biological hazards of concern in most countries include Salmonella spp, Campylobacter spp, pathogenic E. coli. Additionally, antibiotic resistance compounds the persistence of these pathogens along the value chain. The issue of antibiotic residues continues to be an added challenge to the sector.

5.2.4 Impact of food safety challenges on health, trade and economy

Food safety hazards pose serious public health concerns and contribute to the global burden of food borne diseases. This burden is substantial to an extent that about one in 10 individuals fall ill and 33 million lives are lost annually (WHO, 2020). Food borne diseases can be deadly especially in children under the age of five accounting for about one in every three deaths (WHO, 2015). Food borne diseases are due to food infection (cholera, listeriosis, salmonellosis, campylobacteriosis) (Gupta, 2017) and food intoxication (aflatoxicosis, heavy metal, pesticides and other chemical poisoning). Further, the burden of food borne diseases is exacerbated by antimicrobial resistance (AMR) that complicates treatment of diseases (Stewardson et al, 2016). Estimates of the risks and burden of foodborne disease in most countries in Sub-Saharan Africa are limited.

In addition to health impacts, foodborne diseases also negatively impact on the economy of low and middle income countries. According to World bank, 2019 global estimates of economic loss as a result of loss in total productivity amounts to US$ 95.2 annually, while an estimated US$ 15 billion is spent on treatment of foodborne diseases. Thus highlighting the fact that economic impacts of foodborne diseases are quite substantial and require remedial actions. However, the implementation of robust food safety prevention and control systems to minimize the occurance of foodborne diseases requires a cost-benefit analysis to determine the net benefits which would inform governments in efficiently allocating funds among competing needs. Nevertheless, the need to estimate costs associated with preventing and treating foodborne diseases versus the benefits has been constrained by the lack of accurate data on the full extent and economic costs of foodborne diseases in low and middle income countries (WHO, 2016).

For purposes of regional and international trade, food products must meet sanitary and phytosanitary (SPS) standard requirements. Countries in SSA are affiliated with the World Trade Organisation (WTO) and regional bodies such as Southern African Development Community (SADC) and Common Market for Eastern and Southern Africa (COMESA) and have the obligation under the agreements with these organisations of applying sanitary and phytosanitary measures. For example the WTO-SPS Agreement clearly sets out the importance of SPS measures to protect human, animal and plant life or health and facilitate safe trade while allowing countries to put in place any measure to protect human, animal and plant life or health. In most cases, foods from the Sub-Saharan region fail to meet SPS requirements and

hence do not benefit from lucrative markets. This translates into potential economic losses. This is in part due to social economic status, particularly of the rural population, inadequate basic knowledge of food safety management systems such as Good Agriculture Practices (GAPs), Good Veterinary Practices (GVPs), Good Manufacturing Practices (GMPs), Good Hygiene Practices (GHPs), Hazard Analysis Critical Control Points (HACCP) particularly among Small and Medium Enterprises (SMEs), coupled with inadequate monitoring and surveillance of food produced by farmers for safety. Further, there is inadequate basic equipment for proper thermal processing, cooling and sterilization, packaging and labelling of food for SMEs. Inadequate transport, lack of proper systems to facilitate traceability in animal and plant products from farm to fork and lack of proper channels of knowledge and technology transfer from researchers to stakeholders have also been identified as other factors affecting food safety in the region.

5.2.5 Food safety Indicators in Food Systems

Food safety indicators are important for monitoring food control systems to protect the consumer and ensure that all foods along entire value chains are safe, wholesome and fit for human consumption. Inherently, these indictors must help identify food safety issues where remedial actions must be developed to improve the efficacy of the food control systems. It must be pointed out that there is no consensus on specific food safety indicators among international food safety bodies. As the Codex guideline suggests, it is ideal for the national competent authority to develop its own indicators in order to capture country-specific capacities and situations (FAO, 2017). For this discussion paper, selected food safety indicators based on the interations (presentations during the consortium meeting) with FSLs within the framework of this project have been compiled and summerised in section 9.2 of this discussion paper. These may be useful in assessing the general food safety situation of different FSLs but specific checklists may be designed depending on the context for assessing food safety parameters such as hygiene, infrastructure design, and processing equipment.

6. Postharvest improvement options

This section presents some of the possible improved post-harvest practices and technologies that the FSLs could adopt to enhance the food safety situation and reduce food losses or waste. The innovations and choice of which practices and technologies to be adopted by the FSL actors will be co-created

between the researchers in the HFA project and the actors in the food supply chains of the FSLs. Co-creation is considered as the cornerstone of the HFA project to increase the chances of adoption and sustained use of the adopted practices and technologies. The listed practices and technologies have been identified through literature review and preliminary information from the FSLs. Preliminary food safety gaps and food loss or waste factors have been identified through literature review and information from FSLs. It must be noted that detailed food safety and food loss or waste factors will be identified through co-creation with the food supply chain actors in the FSLs. Therefore, the practices and technologies to be finally adopted will highly depend on the perceptions of the FSL actors and will not be limited by what has been preliminary proposed here. WP4 is proposing to introduce and/or popularize the following postharvest practices and/or technologies for adoption in selected FSLs to improve food safety and reduce losses or waste in fruits & vegetable, fish and poultry meat supply chains:

6.1 Postharvest handling improvements: Fruits and Vegetables

i. Enhance training in post-harvest handling practices that promote food hygiene, mostly targeting actors at the farm production, transportation and trading stages;
ii. Explore the possibility of enhancing the use of pre-harvest (near harvest) solutions, which include the use of a range of fertilizers and sun guard solutions. Preliminary informant interviews with FSL-Chongwe has revealed that agricultural pre-harvest interventions (near harvest) enhance post-harvest performance of fruits and vegetables;
iii. Construction of on-farm shades to improve the cooling of fruits and vegetables immediately after harvest. This will solve the problem of fruits and vegetables accumulating heat from the sun during harvest;
iv. Construction of Zero Energy Cool Chambers (ZECC) (Figure 6) at farm level to cool fruits and vegetables in-storage waiting to be delivered to the market (PI LLC, 2017). There are several size possibilities, which include less than 100kg model, 100kg model, 1 ton models and more than a ton models. The ideal sizes will depend on the capacity of the farmer;
v. Construction of Zero Energy Cool Chambers (ZECC) (PI LLC, 2017) at trading level (markets) to cool fruits and vegetables in-storage as the selling of fruits and vegetables takes place. Here, the size possibilities should be the "more than 100kg" model. The traders in FSLs will help decide on the ideal capacity of the ZEEC. At the trading stage, especially for open markets, the communal usage models, where several small fruit and vegetable traders could communally use the ZEEC will be explored;.
vi. Possibilities of construction of COOLBotsTM (Figure 6) cold rooms (PI LLC, 2017) at the farm and trading stages of the supply chains will also be explored. The likelihood of adoption success for the COOLBOT is much lower than the ZEEC's because the

material and energy costs involved with the construction and maintenance of the COOLBotsTM;

vii. Encourage the use of sorting/grading/packing tables (PI LLC, 2017) on-farm for fruits and vegetables to minimize soil microorganism contamination after harvest which compromises food safety and reduces shelf life, as the current practice is to pile the produce on the soil during harvest. The adoption rate for this simple technology is anticipated to be low for small scale farmers, while it may be high for the farmers targeting supermarkets. This technology could be cheaper using locally available materials;

viii. Fruit farmers whose main target is to supply supermarkets will be explored for the possibility of introducing or enhancing the use of the following simple technologies:
    a. Sizing rings - Size rings (PI LLC, 2017) are used for grading fruits according to the size of fruit. This is important for supermarkets where prices of fruits depend on the size;
    b. Colour charts – are used for grading fruits according to their colour due to different ripening stages (PI LLC, 2017). Ripe fruit can be sorted out and sold immediately, while the unripe could be stored to be sold later. This practice enhances shelf life extension. In certain instances, colour differences also lead to differentiated pricing. The project will endeavour either to develop colour charts using the local fruits or adapt existing colour charts from elsewhere and popularize their use in FSLs; and

ix. Explore the possibility of introducing fruit and vegetable driers. Most fruits and vegetables are available during the rainy season, whereas they are scarce during the dry season. This leads to higher food losses during these abundance periods. The challenge in the use of driers has been the low adoption rates by the actors, as the solar dryer options do not work efficiently due to short sunlight during the rainy season, among other contributing factors.

All the raw materials for the construction of ZEEC's will be locally sourced. The proposed practices and technologies are aimed at extending the shelf life of fruits and vegetables as they go through the various stages in the supply chain. These are also aimed at improving the food safety situation as low temperature minimizes the multiplication of any microorganisms that may be on the produce from the farm or any other stage in the food supply chain.

Figure 6. Small sized Zero Energy Cool Chamber (ZEEC) (left) and a COOLBotTM (right) for demonstration and research purposes at the School of Agricultural Sciences of the University of Zambia.

6.2 Postharvest handling improvements: Fish

i. Enhance training in post-harvest handling practices that promote food hygiene, mostly targeting actors at the farm production, transportation and trading stages such as:
    a. Good pre-harvest practices that minimize contamination of fresh fish with microbiological, chemical and physical hazards at production stage;
    b. Good practices that minimize cross-contamination of fresh fish at harvest, during transportation and trading stages of the fish supply chain; and
    c. Proper usage of ice for fresh fish immediately after harvest, during transportation and trading stages of the fish supply chain. Transportation here refers to the use of non-refrigerated transport vessels.

ii. Common processing activities conducted on fish in Africa are drying and, to a lesser extent, filleting of fresh fish. They are associated with fish losses and unhygienic conditions, respectively. The interventions required here include:
    a. design and construction of cost effective and efficient drying kilns; and
    b. training in Good Manufacturing Practices (GMPs) to the fish processors.

6.3 Post-mortem improvements: Poultry meat

i. Enhance training in good livestock production practices that minimize contamination of poultry meat with microbiological, chemical and physical hazards at production stage;
ii. Design and construction of slaughtering facilities to improve hygiene and meat quality for small scale poultry farmers and processors;
iii. Enhance training in Good Manufacturing Practices (GMPs) for small scale poultry processors to minimize cross-contamination of poultry meat with microbiological, chemical and physical hazards at slaughtering/processing, transportation and trading stages; and
iv. Enhancing the fresh poultry meat cold chain through training on the use of ice for cooling of fresh poultry carcasses during and immediately after slaughter for off-grid farms, and during transportation in non-refrigerated vessels from the farm to the markets.

7. Conclusion

This paper has discussed the food loss or waste and food safety challenges and gaps in the postharvest (WP4) and reviewed current technologies used in the vegetable & fruits, fish & poultry meat supply chains of the Food System Labs (FSL) in the HFA project. Literature review has highlighted that while some data on food loss exists at national level, it is scarce at localized FSL level. Therefore, there is need to collect baseline data on food loss and food safety challenges in the FSLs, which will be useful for assessing the effectiveness and impact of the interventions that the HFA project would have introduced or enhanced for the benefit of the FSLs. However, there is no contention of the fact that there are high food losses and many food safety challenges in the vegetable & fruits, fish &poultry meat supply chains of the FSLs. The paper has also noted that there are several food loss assessment methodologies used in literature, and therefore recommends the use of the 4S FAO methodology in the HFA project to ensure comparison of results. On the food safety front, the paper has found two main categories of hazards of concern, namely, chemical and biological hazards for the three selected supply chains. One of the critical postharvest challenges common for both food loss and food safety, and for the three selected supply chains is the lack of or limited availability of cold chain facilities in all the FSLs. Therefore, the paper has proposed introduction of technologies and practices that will ensure that the cold chain is adhered to and maintained in the supply chains. Food safety and food loss challenges cut across sectors of the value chains and therefore addressing these challenges requires a multi-sectoral and integrated approach

involving all the relevant stakeholders. This requires capacity building at all levels, infrastructure and adequate resources to ensure food safety thereby facilitating trade and improving public health.

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9. Appendix

9.1 Food Loss Indicators

9.1.1 Food loss assessment methodology

Selection of the commodity (FSLs must be specific on the commodity)

Determine the food supply chains of the commodity. Begin with key informant consultations to have an indicative FSC, which will initially be useful in the food loss assessment

Select important channel(s) for detailed data collection on food loss (criteria to be discussed)

For the food loss assessment, preferably use the 4-S FAO methodology which consolidates the screening, survey and load tracking methods. For details on the methodology, refer to FAO and Save Food (2014).

9.1.2 Food loss indicators in supply chains

For any loss assessment, endeavour to at least collect the following information:

Stage in the Food Supply Chain	Indicator
General information	Socio-demographic information of the respondent (farmer, fisher-folk, processor, trader…)
Harvesting stage	✓ Variety/Breed (why does the farmer use that variety/breed) ✓ Quantity harvested (kg, tons,…) ✓ Harvesting practices (harvest times, use of equipment, type of equipment, any other relevant practices….) ✓ Maturity stage at harvest (include criteria determining the readiness for harvest) ✓ Immediate harvest practices (packaging – bulking, individual packaging, material, size, design, source of packaging; Length of stay in field before the next stage; sorting or no sorting; grading or no grading; do they weigh) ✓ Who do you supply your commodity to (specify whether individual traders/processors, SME or large scale traders/processors…) ✓ Quantification of the loss by type ✓ Proportion of actors on FSC incurring the type loss, disaggregated by gender ✓ Determine how mechanically damaged and decayed commodity is disposed/utilized ✓ Market price of commodity ✓ Price of commodity when quality has reduced ✓ Causes of loss by loss type from the actor's perspective ✓ Other indicators deemed important according to the supply chain including causes of quantified losses ✓ Existing or past interventions (by NGO, government, donors, actor, etc.) past 5 years that the actor benefited from to minimize loss ✓ Potential interventions to minimize losses from the actor's perspective ✓ Cost of intervention suggested by the actor

Transportation stage [On-farm (Harvest to storage) and distribution during trading]	✓ Type of transport vessel (closed vs open vessels, refrigerated vs cold facilitated packaging..) ✓ Type of transportation packaging (also state whether bulk or individual packaging) ✓ Who do you supply your commodity to (specify whether individual traders/processors, SME or large scale traders/processors…) ✓ Distance to the next stage ✓ Usual time to the next stage ✓ Quantification of the loss by type ✓ Proportion of actors on FSC incurring the type loss, disaggregated by gender ✓ Determine how mechanically damaged and decayed commodity is disposed/utilized ✓ Market price of commodity ✓ Price of commodity price when quality has reduced ✓ Causes of loss by loss type from the actor's perspective ✓ Other indications deemed important according to the supply chain including causes of quantified losses ✓ Existing or past interventions (by NGO, government, donors, actor, etc.) past 5 years that the actor benefited from to minimize loss) ✓ Potential interventions to minimize losses from the actor's perspective ✓ Cost of intervention suggested by the actor
Storage stage (on-farm, at processing, at trading)	✓ Quantity stored ✓ Type of storage facility ✓ Criteria for suitability of storage of the commodity/product ✓ Packaging type for products ✓ Duration of storage ✓ Pre-storage, on-storage and any post-storage treatment (including chemical,…) ✓ Quantification of the loss by type ✓ Proportion of actors on FSC incurring the type loss, disaggregated by gender ✓ Determine how mechanically damaged and decayed commodity is disposed/utilized ✓ Market price of commodity ✓ Price of commodity price when quality has reduced

	✓ Causes of loss by loss type from the actor's perspective ✓ Other indicators deemed important according to the supply chain including causes of quantified losses ✓ Existing or past interventions (by NGO, government, donors, actor, etc.) past 5 years that the actor benefited from to minimize loss) ✓ Potential interventions to minimize losses from the actor's perspective ✓ Cost of intervention suggested by the actor
Processing stage	✓ Length of time in processing business ✓ Sources of raw material (preferably, by proportion…) ✓ Process (flow diagram) ✓ Criteria for suitability for processing of the commodity/product ✓ By-products and use ✓ Packaging type for products and by-products ✓ Who do you supply your commodity to (specify whether individual traders/processors, SME or large scale traders/processors…) ✓ Quantification of the loss by type ✓ Proportion of actors on FSC incurring the type loss, disaggregated bygender ✓ Determine how mechanically damaged and decayed commodity is disposed/utilized ✓ Market price of commodity ✓ Price of commodity price when quality has reduced ✓ Causes of loss by loss type from the actor's perspective ✓ Other indicators deemed important according to the supply chain including causes of quantified losses ✓ Existing or past interventions (by NGO, government, donors, actor, etc.) past 5 yearsthat the actorbenefitedfrom to minimizeloss) ✓ Potential interventions to minimize losses from the actor's perspective ✓ Cost of intervention suggested by the actor

Trading stage (wholesale, retail, streetvending, open markettraders,….)	✓ Sources of the commodity (preferably by proportion) ✓ Criteria for suitability trading of the commodity/product ✓ Packaging type for products and by-products ✓ Who do you supply your commodity to (specify whether individual traders/processors, SME or large scale traders/processors…) ✓ Quantification of the loss by type ✓ Proportion of actors on FSC incurring the type loss, disaggregated bygender ✓ Determine how mechanically damaged and decayed commodity is disposed/utilized ✓ Market price of commodity ✓ Price of commodity price when quality has reduced ✓ Causes of loss by loss type from the actor'sperspective ✓ Other indicators deemed important according to the supply chain includingcauses of quantified losses ✓ Existing or past interventions (by NGO, government, donors, actor, etc.) past 5 years that the actor benefited from to minimize loss) ✓ Potential interventions to minimize losses from the actor's perspective ✓ Cost of intervention suggested by the actor

Determining Critical Loss Points (CLP): After determining the indicators, determine critical stages (stages with high losses) in each supply chain

Synthesis: Using the data collected in the food supply chains and specific food supply chain channels, determine the causes and possible interventions to mitigate the losses

9.2 Food Safety Indicators

9.2.1 System level indicators

Parameters	Food Safety indicators
Governance	▪ Government commitment to protect human health ▪ Presence of an agency to ensure food safety ▪ Presence of a an advisory (scientific and body providing advice to government on food safety and quality issues ▪ Presence of an agency mandated to collects data on food safety and quality issues ▪ The use of risk analysis to inform and support decision-making and establish food safety control measures ▪ Financial commitment to support food control systems ▪ The existence of a Codex Committee
Legislation and implementation of Regulations	▪ Food related laws and regulations in place ▪ Implementation of food related laws and regulations ▪ Mandatory notification with regard to food safety
Standards	▪ Presence of food standards agencies or bodies ▪ Development of standards ▪ Compliance with local and international food safety and quality requirement and obligations
Inspection	▪ Presence of inspection agencies or bodies ▪ Inspection of foods along the value chain (production, processing, distribution and retail), including sampling & testing of raw materials and finished products ▪ Inspection of foods and feeds at ports of entry, warehouses and retailers ▪ Risk-based audits ▪ Registration of all food processing factories
Certification	▪ Presence of certification agencies or bodies ▪ Certification & Testing of Food and Food products (e.g. Meat, Fruits and Vegetables), including labeling for local consumption & export
Training ▪ Food Inspectors ▪ Food Producers ▪ Food Handlers	▪ Availability of training opportunities for food inspectors to perform official food controls ▪ Availability of training opportunities for food producers and food handlers in food safety management systems (PRPs, HACCP and ISO (International Organization for Standardization) standards
Laboratory Testing Facilities	▪ Availability of accredited laboratory facilities ▪ Use of Standard Operating Procedures (SOPs) ▪ Chemistry (Heavy metals, mycotoxins, pesticides, food additives and allergens) ▪ Microbiology (microbial contamination and pathogens) ▪ Entomology (poisonous insects)

Parameters	Food Safety indicators
	▪ Biotechnology - Genetically Modified Organisms (GMOs), molecular biology
Public Education	▪ Public education & awareness on food safety issues
Communication	▪ working mechanisms for information, education and communication with stakeholders along the value chain
Foodborne outbreaks or Illnesses	▪ Number of outbreaks/ illnesses in the area
Food product labelling	▪ Products well labeled for traceability

9.2.2 Food Supply Chain Indicators

Farm level		**Parameters**	**Remarks**
Food products	Microbiological safety indicators • General contamination / cross contamination • Hygiene • Pathogens • Mycotoxins (when necessary) • Storage	Total viable counts	For general hygiene levels and contamination of raw materials/products
		Enterobacteriacae	Both faecal and environmental contamination (soil, dust, water, utensils and equipment)
		Faecal coliforms	General faecal contamination
		E. coli	For animal /human faecal materials. Indicates for potential pathogens of faecal origin
		Bacillus cereus	when necessary for spore formers on raw materials, surfaces
		Salmonella spp	
		Yeast and molds, Aflatoxins	For dry water food products (herbs)
		Temperature	Storage room, refrigeration, freezing, heating
		Relative Humidity	Storage room
		Water activity	For dry and fresh products
	Chemical safety indicators	Heavy metals	Ld, Hg, Cu, As
		Pesticides/ herbicides	Types used, sources, permitted, storage

		Disinfectants	Types used, sources, permitted, storage
		Food additives	Types used, any overuse or misuse
Handlers, equipment, utensils and food contact surfaces and packaging materials (swabs)	Microbiological safety indicators • General contamination / cross contamination • Hygiene • Pathogens	Total viable counts	For general hygiene levels and contamination of raw materials/products
		Enterobacteriacae	Both faecal and environmental contamination (soil, dust, water, utensils and equipment)
		Faecal coliforms	General faecal contamination
		Staph aureus	General hygiene
Soil	Chemical safety indicators	Heavy metals	Ld, Hg, Cu, As
Water	Microbiological safety indicators	Enterobacteriacae	Both faecal and environmental contamination (soil, dust, water, utensils and equipment)
		Faecal coliforms	General faecal contamination
		E. coli	For animal /human faecal materials. Indicates for potential pathogens of faecal origin
	Chemical safety indicators	Heavy metals	Ld, Hg, Cu, As
Fertilizers	Chemical safety indicators		Types, sources, permitted, storage, use
Retail level (markets) e.g. Lusaka FSL			
Food products	Microbiological safety indicators • General contamination / cross contamination • Hygiene	Total viable counts	For general hygiene levels and contamination of raw materials/products
		Enterobacteriacae	Both faecal and environmental contamination (soil, dust, water, utensils and equipment)
		Faecal coliforms	General faecal contamination

	• Pathogens	E. coli	For animal /human faecal materials. Indicates for potential pathogens of faecal origin
		Bacillus cereus	when necessary for spore formers on raw materials, surfaces
		Yeast and molds	When necessary
	Chemical safety indicators	Heavy metals	Ld, Hg, Cu, As
		Pesticides/ herbicides	Types used, sources, permitted, storage
		Disinfectants	Types used, sources, permitted, storage
	Storage	Temperature	Room, refrigeration, freezing, heating
		Relative Humidity	Storage room
		Water activity	For dry and fresh products
Water (for cleaning produce, utensils, food contact surfaces and for sprinkling to keep the food produce from drying out)	Microbiological safety indicators	Enterobacteriacae	Both faecal and environmental contamination (soil, dust, water, utensils and equipment)
		Faecal coliforms	General faecal contamination
		E. coli	For animal /human faecal materials. Indicates for potential pathogens of faecal origin
	Storage	Temperature	Room, refrigeration, freezing, heating
	Chemical safety indicators	Heavy metals	Ld, Hg, Cu, As
Handlers, equipment, utensils and food contact surfaces and packaging	Microbiological safety indicators • General contamination / cross contamination • Hygiene	Total viable counts	For general hygiene levels and contamination of raw materials/products
		Enterobacteriacae	Both faecal and environmental contamination (soil, dust, water, utensils and equipment)

materials (swabs	• Pathogens	Faecal coliforms	General faecal contamination
		Staph aureus	General hygiene

9.3 Key findings on food loss, safety and packaging from focus group discussions in FSL Chongwe

Food loss	**Food safety issues**	**Food Packaging issues**	**Pest and weed control**	**Storage facilities**
Limited knowledge on preservation techniques was given as a contributing factor to food waste, as well as poor storage facilities.	The use of pesticides. More especially when crops have been sprayed with chemicals such as pesticides and then being harvested before the pesticide or other chemical sprayed wears out. Examples of crops affected include tomatoes, cabbages and rape.	Farmers package vegetables like rape in empty used fertilizer or animal feed sacks.	Some farmers use conservation farming techniques. Others reported using both herbicides and pesticides to control weeds and pests respectively. Some farmers also reported having attended workshops on conservation farming which had topics on food safety. The components on food safety covered aspects of pesticide and herbicide use.	Farmers expressed a general lack of refrigeration facilities. When produce is harvested it is usually stored under a tree shed whilst waiting for transportation to markets
Lack of transport to move the produce from the field to collection point, was reported as a contributor to food	The use of sewerage water for irrigation was also cited as a food safety concern.	For cabbages, no packaging is used, they just load them onto an open van for transportation to the market.	To control rodents, farmers buy drugs (indosid, other poisons) and sometimes use cats.	Sellers spread out on sacks and sprinkle water on them to try and keep them fresh for longer.

loss because the produce would be manually carried on the head and in the end would lead to physical damage.				
Harvesting at the wrong time- for crops like soya was reported as contributing to food loss.	The failure to clean produce after harvesting was also reported as a concern and in some cases the use of recycled water sprinkled on vegetables as a way of cleaning them and to keep them fresh.	Common modes of transport in the area: inlcuded open vans, light trucks and a few use bicycles.		Onions and potatoes are put in the sun to dry.
Food loss was also reported to occur during processes like shelling (mainly groundnuts, soya and maize).	For some crops like cabbages they are usually not washed and are left on the floors, which is also a source of contamination.	Farmers use sacks for leafy vegetables and wooden crates for tomatoes/guavas/lemons. Cabbage just thrown into the back of vans.		If leafy vegetables are brought back from the market, sometimes they are sun dried and sold as dry vegetables.
Food loss/waste also experienced when the farmers go with a lot of produce to the market, find it	Produce transporters were also cited as other source of food contamination, especially cross	The unit of transaction for leafy vegetables are generally sacks. When taken to market and the charge for		Fruits are just thrown away if they have not been sold for a few days, but usually just drop

flooded and when the cost of transporting the produce back to the farm outweighs that of leaving the produce, they end up dumping or discarding the produce especially for leafy vegetables.	contamination during transportation. Especially when the same transportation is used to tranfer vegetables from different producers.	transportation is usually per sack without much regard for the quantity of the vegetable in the sack. Even marketeers come with sacks for exchange when buying a sack of vegetables.		prices (to get rid of them) so that they are not burdened with storage of the fruit and vegetables which will go bad.
Long distances to the markets also was cited as significantly contributing to losses in vegetables.	Non observance of Pre-harvest Interval (PHI) of pesticides and other chemicals used by farmers and lack of a monitoring systems for chemical residues. Farmers also lack knowledge on pre-harvest interval indicators	Some of the produce (okra, pumpkin leaves, cowpeas leaves and per peri) is sun dried and packaged in sacks.		
Lack of proper transport, coupled with poor roads, ranked as one of the	Wrong application of fertilizers by farmers.	The sacks are washed and dried before use. Usually, the same sacs are used for other farm produce.		

main causes of food losses.				
Use of inorganic fertilizers leads to shorter shelf life than organic fertilizers	Lack of training in the proper use of organic manure (organic farming).			
Sharp fluctuations in prices especially after rain season due to high supply and low prices, leads to food commodities to stay on the shelves longer	Poor handling of food commodities during retailing especially traders with babies.			

9.4 9.4 Key findings on food loss, safety and packaging from focus group discussions in FSL Lusaka

Food losses	**Food safety issues**	**Packaging, Transport and distribution models**	**Storage**
Vegetable losses may be as high as 50% per 50 Kg of leafy vegetables, which has mainly been due to dropping in sales attributed to the CoVID 19 pandemic. For tomato, around 13% of the losses are incurred and mostly attributed to physical and physiological damage during transportation and storage at the market respectively.	During transportation, Leafy vegetables are packaged in a variety of used polyethylene bags which sometimes could be contaminated with chemical fertilizers.	The main forms of transport include open vans, light trucks and bicycles.	There are no appropriate storage facilities at the markets.
The traders prepare small portions to avoid wastage and leftovers are taken to their homes.	During night storage, leafy vegetables are covered with a moist polyethylene sack. This could be a source of contamination as the quality of water used varies.	Green leafy vegetables are loosely packaged in a 50 Kg polyethylene bags while tomatoes are packaged in wooden boxes and plastic crates	Tomatoes are openly stored in wooden boxes or plastic crates without a controlled indoor climate.
	Traders do use pesticides for dry products such as beans, cowpeas and fish. They buy the pesticides from chemists and drug stores.	Vegetables not sold at the end of the day are stored in cupboards within the market	Leafy vegetables are stored at the vendor's stores with a moist polyethylene sack covered on top of the produce.

	Traders leave their produce in the open leaving it prone to attack from pests such as rats and cockroaches	Foods packaged are mostly dry foods (vegetables, beans, ground nuts) and others include okra, soda and peri-peri.	Chemical drugs bought from vendors and drug stores are used to control cockroaches and rodents such as rats.
	Toilet facilities with hand wash basins also available within the market.	Fruits such as bananas, apples, grapes, *masau*, *mpundu* and *masuku* are difficult to packages and easily get damaged	
	One of the challenges facing markets is the accumulation of market garbage, due to limited s uncoordinated collection systems.		
	To keep flies away as well as keep fish fresh, traders sprinkle water on fish using improvised sprinklers made from sacks and a stick.		
	Dried beans and other legumes are treated with some unknown powdered chemicals. This powder makes the beans look dull. When traders buy for re-sale they then use maize meal to make the beans shiny.		