The Post-Harvest Losses: The Consequences for Africa

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Abstract—

Introduction: *The Food and Agricultural Organization predicts that about 1.3 billion tonnes of food are globally wasted or lost per year. This is equivalent to 30% of food produced for human consumption for the same period. Some reports have estimated that this lost or wasted food can be used to feed 1.6 billion people every year.*

Problem Statement: *Global food waste is a far-reaching problem with tremendous financial, ethical and environmental costs. The amount of food lost or wasted costs US$2.6 trillion annually and is more than enough to feed about 815 million hungry people in the world four times over.*

Methodology: *The study is mainly qualitative with some quantitative in scope making use of secondary data (literature from journals, working papers, unpublished theses, publications from government, World Bank and similar institutions) and global agribusiness industry.*

Results: *The review found out that, via meta-analysis, evidence of post-harvest losses in Africa is spotty and quantitative estimates are often derived from inadequate datasets. The major reason for many post-harvest losses estimates is weak assessment methodologies. The world's increasing population and demand for food, reducing food loss and waste is one of the challenges globally. Food loss and waste have significant negative food-security, economic and environmental impacts. The value of annual food loss and waste globally is about US$1 trillion and one billion tonnes in quantity.*

Conclusion: *Although reduction of post-harvest food losses is a critical component of ensuring future global food security, however, production resources including land, water and energy are at the moment limited and inelastic*.

Keywords— Food Security; Post-harvest Losses and Waste; Supply Chain; Qualitative and Quantitative Losses.

I. INTRODUCTION

Current world population (8.2 billion June 2025) is expected to reach 9.7 billion by 2050, withAfrica contributing more than half of that increase, further adding to global food security concerns [1]. This increase translates into 33% more human mouths to feed with the greatest demand growth in the poor communities of the world, Africa for example. According to [2], food supplies would need to increase by 70% (estimated at 2005 food production levels) in order to meet the food demand in 2050 [1]. A significant part of this growth will take place in developing countries, where steadily increasing urban population continue to create complex and lengthy food supply chains involving many actors, presenting challenges in developing safe, and nutritious food that is of good quality [3]. Post-harvest losses (PHL) are a measurable reduction in foodstuffs, which may affect quantity or quality [4]. For many households, such losses threaten food nutrition, and income security [5]. They also contribute to high food prices by removing part of the food from the supply chain. Food availability and accessibility can be increased by upping production, improving distribution, and reducing the losses. Thus, reduction of post-harvest food losses is a critical component of ensuring future global food security. However, production resources including land, water and energy are limited and inelastic [6].

The Food and Agricultural Organization (FAO) forecasts that about 1.3 billion tonnes of food are globally wasted or lost per year [7]. This is equivalent to thirty percent of food produced for human consumption for the same period. Some reports have estimated that this lost or wasted food could be used to feed 1.6 billion people every year [6].Food losses refer to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption [7]. They state that food waste or loss is measured only for products that are directed to human consumption, excluding feed and

parts of products which are not edible. Reduction in these losses would increase the amount of food available for human consumption and enhance global food and nutrition security, a growing concern with rising food prices due to growing consumer demand, increasing demand for biofuel and other industrial uses and increased weather variability ([8]; [9]). A reduction in food losses also improves food and nutrition security by increasing the real income for all the consumers [10].

The loss of harvested food commodities can be qualitative or quantitative. Quantitative losses are easy to determine and report since they constitute a physical reduction in the marketable volume and can be easily measured. Globally, quantitative grain losses are estimated to be ten to twenty percent of the total volumes [6]. Qualitative losses refer to deterioration of nutritional quality, safety and grade. Qualitative loss data is hardly ever reported. But it is a loss that must concern everyone. For example, the levels of qualitative losses due to aflatoxin contamination, although not reported, have dire long-term effects on health. Chronic dietary exposure to low doses of aflatoxin is a known risk factor for liver cancer and other health-related issues.

Over the past decades, significant forms and resources have been allocated to increase food production. For example, 95% of the research investments during the past 50 years were reported to have focused on increasing productivity and only five percent directed towards reducing losses ([11]; [12]; [13]). Increasing agricultural productivity is critical for ensuring global food and nutrition security, but this may not be sufficient [1]. Food production is currently being challenged by limited land, water and increased, weather variability due to climate change. To sustainably achieve the goals of food and nutrition security, food availability needs to be also increased through reductions in the post-harvest process at farm, retail and consumer levels [1].

Food losses do not merely reduce food available for human consumption but also cause negative externalities to society through costs of waste management, greenhouse gas production and loss of scarce resources used in their production [1]. Food loss is estimated to be equivalent to 6-10% of human-generated greenhouse gas emissions ([7]; [14]). A significant contributor of this problem is through methane gas generation in landfills where food waste decomposes anaerobically [15]. The United States Environmental Protection Agency (USEPA) reports that in the United States of America about 31 million tonnes of food waste accounted for 14% of the 2008 solid waste produced in the country [16] costs roughly US$1.3 billion to landfill ([17];[15]).

A study by the Institute of Mechanical Engineers indicates that current agricultural practice uses 4.9 Gha (global hectares or 4,931million hectares) of the total 14.8 Gha (14,894 million hectares) of land surface on Earth [18]. Agricultural production in addition uses 2.5 trillion m^3 of water per year and over 3% of the total global energy consumption [18]. With estimated food losses of about 30-50% of total production, this translates to wasting 1.47 – 1.96Gha of arable land, 0.75 – 1.25 trillion m^3 of water and 1% to 1.5% of global energy [18].

Given the significant role food loss reductions could have toward sustainably contributing to global food security, it is important to have reliable measures of these losses. Unfortunately, most of the available post-harvest loss and food waste estimates are based on the anecdotal stories with few actual measured or estimated numbers. Moreover, these numbers, in turn, feed into estimates of food availability which are widely used in food and nutrition security assessments and policy analysis.

The history of food waste is closely linked to globalization [19]. In an ever more networked world, supply chains get longer, and everything is available everywhere – Indian mangoes in Germany and American apples in Indonesia – the whole year round. On that often-long journey from farm to table, food is lost or wasted at every stage, and fresh foods such as fruits, vegetables, dairy and meat are particularly vulnerable[19].

Food loss typically refers to food lost in earlier stages of production such as harvest, storage and transportation. Food waste refers to items that are fit for human consumption but thrown away, often at supermarkets or by consumers. Food loss and waste and their ripple effects on the environment, society and economy have become an increasing global concern. With every gram of food produced and then wasted, there are associated wastages in water, energy, capital, nutrition and other related resources.

The total volume of water used to produce food that is lost on an annual basis is equivalent to the yearly flow of the Volga River in Russia which is (8060 cubic metres/second); it is three times the volume of Lake Geneva (89 km3)[19]. In terms of land, 28% of the global arable area (1.4 billion hectares of land) is used to produce food that is lost or wasted annually[19].

Furthermore, food waste has been noted to immensely contribute to climate change through greenhouse gas (GHG) emissions. The carbon footprint of wasted food is approximately 3.3 billion tonnes of carbon dioxide (CO_2) released into the atmosphere on an annual basis.

In Africa, PHL account for up to a fifth of harvests, thereby negating the benefits of investments aimed at ensuring increased productivity towards food and nutrition security[19]. The Inaugural Biennial Review Report (BRR) released by the African

Union Commission in January 2018 shows that the continent is not on track in terms of its efforts towards the Reduction of PHL, having scored zero in 2017, against a target of 10% towards the 2025 target [19]. A key challenge related to this performance on postharvest management (PHM) is the inability of countries to capture and record data on physical losses, perhaps as a result of unavailability or weak national monitoring and evaluation systems as highlighted by the 2017 BRR.

Generally, any loss of produce translates to lost production resources, mainly land, water, energy and inputs. It is also lost income for the various actors in the supply chain. A 2011 World Bank study estimated the value of African grain losses alone stands at USD4 billion. It has been shown that 470 million smallholder farmers suffer a decline of 15% income, while 25% of fresh water and 20% of farmland is wasted in unconsumed food [6].

II. PROBLEM STATEMENT

Global food waste is a far-reaching problem with tremendous financial, ethical and environmental costs. The causes range from ungraded roads to overly-selective customers, but regardless of cause, we can all pitch in to combat this global issue. An estimated 1.3 billion metric tonnes of food is wasted worldwide each year, one third of all food produced for human consumption according to the FAO. In Africa the losses are even higher, between 30% and 50% (with cereal, the main staple food, postharvest losses estimated to be about 15%, [20]).

The amount of food lost or wasted costs US$2.6 trillion annually and is more than enough to feed about 815 million hungry people in the world four times over. The world food production must increase by sixty percent come year 2050 in order to meet the demands of the growing world population. Yet, more than one third of the food produced today is lost or wasted.

III. METHODOLOGY

This paper reviews the Post-harvest problems/issues. Mainly the consequences of PHL, on the African continent. It is a research review article which is qualitative (some quantitative methods will be used) in its approach; mainly concerned with and verifiable by both experience and observation rather than theory or pure logic. The qualitative method used here is mainly meant to gather data and find meanings, strategies, opinions, experiences related to PHL in Africa and other developing continents, for example, Asia and South America. Comparisons are made with the developed countries.

In order to comprehend on what is currently known about PHL, literature will be drawn from journals, working papers, unpublished theses, publications from government, the likes of FAO, World Bank, Non-Governmental Organisations and global agribusiness industry.

The sequence of this review is to study definitions of PHL; causes of PHL; examples of types of food losses/waste; drivers of food losses; PHL critical points; extent of food losses and waste; energy and food losses; the economic consequences of PHL; indications of results/findings; post-harvest technology objectives; PHL management strategies; and conclusion and recommendations.

IV. LITERATURE REVIEW

4.1 Defining Post Harvest Losses:

It is essential that common ground be established as issues of PHL, food waste, food and nutrition security and other similar terms have oftentimes been confused with each other or are given different meanings within the concept of PHL management. The expression “PHL” means a measurable quantitative and qualitative loss in a given product. These losses can occur during any of the various phases of the post-harvest system. This definition must also consider cases of product deterioration.

Food losses are defined *“as the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption”*([21], p3). Food losses take place at the production, harvesting, primary handling, aggregation, storage, transport, processing, distribution and consumption segments [22]. Food losses occurring on the demand side of the food chain (retail and final consumption) are generally referred to as “food waste”, which relates to retailers’ and consumers’ behavior [23] as quoted by ([21], p3). In [22] Definitional Framework of Food Loss working paper, ‘food loss’ is simply defined as the decrease in quantity or quality of food.

The following was a summary of PHL by [24; 25]:

- Measurable quantitative (volume) and qualitative (nutritional and monetary value) loss in a given agricultural product.
- Occurrence in during various stages of the post-harvest system.
- The physical characteristics considered are shape and size of the produce, moisture content, impurities such as pebbles, soil and plant residues, fragments of glass or metal, animal hairs, excrement, degree of infestation by insects or micro-organisms.
- Rather than actual losses, it would be more accurate to call it restriction in the use of the product.

Consequently, post-harvest is not only multidimensional but multidisciplinary involving the agriculture sector, agri-processing industry, health and nutrition sector, distribution and manufacturing sectors, among others.

Thus, food waste is the loss of edible food due to human action or inaction such as throwing away wilted produce, not consuming available food before its expiry date, or taking serving amounts beyond one's ability to consume [22]. Food waste is strongly linked with the consumer's behavior, that is, consumer's refusal to purchase the food and/or discarding of leftover food[25]. The Definition Framework of Food Loss working paper, "quantitative food loss" is simply defined as the decrease in mass of food [22]. The quantity lost would have either deteriorated rendering it inedible or discarded for failure to meet regulated standards to eat as a food or to use as an animal feed.

The Post-harvest food loss can also be defined as the loss from the stage of harvesting to the stage of consumption which occurs as a result of qualitative loss quantitative loss and the food wastage (by the consumers).

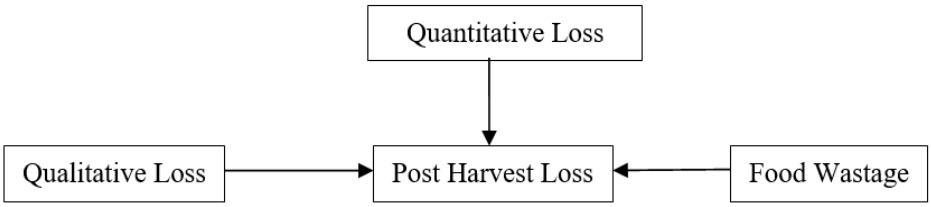

FIGURE 1: Post-harvest food loss components.
Source:27

While, qualitative food loss is when food loses its quality attributes resulting in the deterioration in quality leading to a loss of economic, social and nutritional value[26]. The qualitative loss can occur due to incidence of insect pest, mites, rodents, and birds, or from handling, physical changes or chemical changes in carbohydrates and protein, and by contamination of mycotoxins, pesticide residues, insect fragments, or excreta of rodents and birds and their dead bodies[27]. When this qualitative deterioration makes food unfit for human consumption and is rejected, this contributes to food loss [26].

Post-harvest loss can also be defined as the degradation in both quantity and quality of a food production from harvest to consumption [28]. Quantity losses include those that afford the nutrient/calorific composition, the acceptability, and the edibility of a given product [28]. These losses are generally more common in developed countries [27]. Quantity losses refer to those that result in the loss of the amount of a product [28]. Loss of quantity is more common in developing countries [29].

Therefore, food that was originally meant for human consumption but which fortuity gets out the human food chain is considered as food loss or waste even if it is then directed to a non-food use (feed and bioenergy) [7].

4.2 Causes of Post-Harvest Losses:

In industrialised countries food gets lost when production exceeds demand. In order to ensure delivery of agreed quantities while anticipating unpredictable bad weather or pest attacks, farmers sometimes make production plans on the safe side and end-up producing larger quantities than needed, even if conditions are average. In the case of having produced more than required, some surplus crops are sold to processors of animal feed. To prevent this, [30], suggests that there must be communication and cooperation between and among farmers so that they can reduce risk of overproduction by allowing surplus crops from one farm/region to solve a shortage of crops or any other.

There are generally three main causes of PHL, namely [30]:

- Disease caused by fungi and/or bacteria
- Physical injuries due to insects, mechanical force, chemicals, heat, rain or freezing

- Non-disease disorders resulting from storage conditions that upset normal metabolism when the product is rejected further down the marketing chain.

Post-harvest losses can be categorized into five types:

1) Biological: Pest and disease
2) Chemical: Visible external contamination with pesticides and chemical products, toxics and unpleasant flavor produced by pathogens.
3) Mechanical: Injuries, cuts bruises, grazes, drops, scrapings, shatters during harvesting, packing and transporting.
4) Physical: Heating, cooling, freezing, water loss.
5) Physiological: Sprouting, rooting, senescence and changes caused by transpiration and respiration.

TABLE 1
CAUSES OF TOTAL FOOD LOSS DURING THE POST-HARVESTING CHAIN: SOURCE [31]

Harvesting	Food Storage	Processing	Packaging	Marketing	Consumption
1) Poor production practices 2) Climatic conditions	1) Attack by insect, moulds, rodents, 2) Deterioration 3) Shrinkage 4) Spoilage 5) Humidity 6) mproper handling 7) Temperature	1) Removal of damaged portions. 2) Discarding of substandard product 3) Visual based rejection 4) Package failures 5) Shrinkage	1) Packaging failures 2) Transportation losses 3) Lack of packaging services	1) Improper portioning 2) Supersizing 3) Poor inventory 4) Dented cans	1) Left-overs 2) Impulse buying 3) Infrequent market visits 4) Poor portioning 5) 5. Bulk purchase

Internal and external factors contributing to PHL[28]:

A. Internal Factors:

- *Harvesting.* Time of harvesting is determined by degree of crop maturity and weather conditions. Primary causes of losses at the harvest stage include (1) absence of an established maturity index for some commodities, and/or lack of maturity index for local export markets, (2) low adoption of established indices, as price and distance to market influence adoption and (3) poor weather at harvest time which affects the operations and functionality of harvesting machines or human labour and usually increases the moisture content of the harvested products.
- *Pre-cooling*. Loss at this stage is primarily due to the high cost and lack of availability of pre-cooling facilities, inadequate training on pre-cooling technology at the commercial scale and lack of information on cost benefits of pre-cooling technology.
- *Transportation.* Primary challenges in the transportation stage of the supply chain include poor infrastructure (roads, bridges, communication), and a lack of refrigerated transport. In most developing countries, roads are not adequate for proper transport of horticultural crops. Transport vehicles and other modes of transport, especially those suitable for perishable crops are not widely available. Small-scale producers in Africa have smallholdings and cannot afford to purchase transport vehicles. In a few cases, contract farming arrangements, marketing organisations and cooperatives have been able to provide and acquire transport vehicles but cannot alleviate poor road conditions [27].
- *Storage* (granaries, warehouse, hermetic bins, silos). Facilities, hygiene, and monitoring must all be adequate for effective, long-term storage. Control of cleanliness, temperature and humidity is particularly important. It is also very important to manage pests and diseases can lead to deterioration of facilities and result in losses in quality and food value as well as quantity.

- *Grading.* Proper packing and packaging technologies are critical in order to minimize mechanical injury during the transit of produce from rural to urban areas. Causes of PHL in the grading stages are (a) lack of national standards and poor enforcement of standards (b) lack of skill (c) awareness and (d) financial resources.
- *Packaging and labelling*. After harvest, fresh fruits and vegetables are generally transported from the farm to either a packing house or distribution centre. Farmers sell their produce in fresh markets or in wholesale markets. At the retail level, fresh produce is tied in bundles. This type of market handling of fresh produce greatly reduces its shelf life if it is not sold quickly.
- *Biological.* Biological causes of deterioration include respiration rate, ethylene production and action, rates of compositional changes (associated with colour, texture, flavour and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders and pathological breakdowns. The rate of biological deterioration depends on several environmental factors, including temperature, relative humidity, air velocity and atmospheric composition (concentration of oxygen, carbon dioxide and ethylene) and sanitation procedures ([32]; [27]; [33]).
- *Microbiological.* Micro-organisms cause damage to stored foods (for example, fungi and bacteria). Usually, micro-organisms affect directly small amount of the food but they damage the food to the point that it becomes unacceptable. Toxic substances elaborated by molds (known as mycotoxins) cause loss in food quality and nutritional value.
- *Chemical.* Many of the chemical constituents naturally present in stored foods spontaneously react causing losses of colour, flavours, texture and nutritional value.One such reaction is the mallard reaction that causes browning and discolouration in dried fruits and other product. There can also be harmful chemicals such as pesticides or obnoxious chemicals such as lubricating oil [34].

B. External Factors:

Factors outside of the food supply chain can cause significant PHL. These factors can be grouped into two primary categories, that is, environmental factors and socio-economic patterns and trends.

Environmental factors. Climatic conditions, including wind, humidity, rainfall, and temperature influence both the quantity and quality of a harvest [4]:

- *Temperature*. The higher the temperature the shorter the storage life of horticultural products and the greater the amount of loss within a given time[34].
- *Humidity*. There is movement of water vapour between stored food and its surrounding atmosphere until equilibrium of water activity in the food and atmosphere is reached. A moist food will give up moisture to the air while a dry food will absorb moisture from the air. Fresh horticultural products have high moisture content and need to be stored under conditions of high relative moisture loss and wilting (except for onions and garlic). Dried or dehydrated products need to be stored under conditions of low relative humidity in order to avoid absorbing moisture to the point where mould growth occurs [34].
- *Altitude.* Within a given latitude the prevailing temperature is dependent upon the elevation when other factors are equal. There is on the average a drop in temperature of 6.5^0C [34], for each kilometer increase in elevation above sea level. Storing food at high altitudes will therefore tend to increase the storage life and decrease the losses in food provided it is kept out of direct rays of the sun [35].
- *Time.* The longer the time the food is stored the greater is the deterioration in quality and the greater is the chance of damage and loss. Hence, storage time is a critical factor in loss of foods especially for those that have a short natural shelf life.

Some produce is rejected by supermarkets at the farm gate due to rigorous quality standards concerning weight/mass, size, shape and appearance of crops [7]. This results in large portions of crops not leaving the farms. Even though some rejected crops are used as livestock feed, the quality standards might divert food originally aimed for human consumption to other uses [30]. Supermarkets seem convinced that consumers will not buy food which has the ‘wrong’ weight/mass, size or appearance.

However, surveys done show that consumers are willing to buy heterogeneous produce as long as the taste is not affected [30]. Consumers have the power to influence the quality standards. This could be done by questioning them and offering them a broader quality range of products in the retail stores [23]. Selling farm crops closer to consumers without having to pass the strict quality standards set up by supermarkets on mass, size and appearance would possibly reduce the amount of rejected crops [36]. This can be achieved through, for example, farmers markets and farm shops [30].

Poor storage facilities and lack of infrastructure cause post-harvest food losses in developing nations. Fresh products like fruits, vegetables, milk, meat and fish straight from the farm or after the catch can be spoilt in hot climates due to lack of infrastructure for transportation, storage cooling and markets ([36]; [30]). To prevent this governments should improve the infrastructure for roads, energy and markets. Subsequently, private sector investments can improve storage and cold chain facilities as well as transportation [37].

Failure to comply with minimum food safety standards can lead to food losses and in extreme cases, impact on the food security status of a country[36]. A range of factors can lead to food being unsafe, such as naturally occurring toxins in food itself, contaminated water, unsafe use of pesticides and veterinary drug residues[7]. Poor and unhygienic handling and storage conditions and lack of adequate temperature control can also cause unsafe food[36]. Food chain operators should be skilled and knowledgeable in how to produce safe food. Foods need to be produced, handled and stored in accordance with set food safety standards. This requires the application of good agricultural and good hygienic practices by all food chain operators to ensure that the final food protects the consumer[30].

The attitude of disposing off food products is cheaper than using or re-using in industrialised countries leads to a lot of food waste[37]. This occurs on the food processing lines when carrying out trimming to ensure that the end product comes out in the right shape and size[37]. The trimmings in some cases, could be used for human consumption but are usually disposed of. Food might be lost during processing because of spoilage down the production line. Sometimes errors on the processing line lead to end-products with the incorrect mass, shape or appearance, or damaged packaging, without affecting the safety, taste or nutritional value of the food[37]. In a standardized production line these products often end up being discarded ([30]; [38]).

4.2.1 Types of Post-harvest Losses:

Direct and Indirect Loss: Direct loss is food lost through spillage of crops from bags and consumption by pests. Indirect loss is food waste which occurs at the consumer level, that is, left overs, refusal to purchase.

Weight Loss: The observable loss which can be measured by reduction in moisture content. Prolonged storage, shrinkage, pests, poor packaging, leakages.

Food Loss: Occurs as a result of loss qualitatively and quantitatively.

Qualitative Loss: Deterioration of quality via degradation of nutrients, texture, taste shape, for example, carbohydrates, proteins, vitamins act as food for:

- Weevils – feed inside seed crops where high carbohydrates are located
- Some insects attack the cereal cover rich in vitamins
- Moulds and bacteria attack on high perishable foods (fruits and vegetables) because they have a high moisture content which is fed upon
- Loss due to the excreta of birds and animals, pesticides, pathogenic organisms

Quantitative Food Loss: reduction in weight through heat (moisture loss), rodents, birds, animal, leakages during transportation. Rice, maize, wheat are typical examples.

Seed Viability Loss: reduced viability lowers yields (temperature, moisture, sun)

Commercial Loss: Value of produce goes down because of customer low demand, rejection by down grading. Qualitative and Quantitative losses.

Irreducible Loss: excessive respiration of the product, mechanical rubbing of the grains, shrinkage in the produce, mechanical injuries. To compensate for this, more has to be produced than required.

4.2.2 Main Drivers of Food Losses as observed by [39]:

In developing countries food is lost due to infrastructural constraints including lack of access to modern energy to drive improved food processing technologies and to optimize storing facilities.

- One of the main causes of food losses is biological spoilage due to lack of appropriate storing infrastructure.
- Livestock products, fish, fruits and vegetables lose value very quickly without refrigeration. A large proportion of fresh products such as fruits, vegetables, meat and fish, straight from the catch or the farm are spoiled due to lack of cooling, drying and technologies that would enable safe storage. They lose quantitative and qualitative value if stored in an unregulated environment with high temperatures. They also lose value due to mechanical damage during harvesting and handling and improper post-harvest sanitation.
- Roots and tubers are less susceptible than fruits and vegetable to biological decay but post-harvest storage and processing are required to limit losses. Especially with potatoes for example which require a high humidity environment to prevent sprouting. They are normally stored at a temperature of 4 to 7^{o} C and relative humidity of 90% in a dark location, as potatoes turn green when exposed to light. If storage temperatures are above 7$^{0\ C,}$ the potatoes will startto sprout after two or three months.
- Cereals are the least susceptible to PHL but may be scattered, dispersed and crushed during handling. In developing countries, cereals are often dried directly under the sun on open ground due to lack of appropriate drying technology resulting in losses due to pest and rodent attacks. Losses are even higher under unfavourable weather conditions when open sun drying is not possible. (Suboptimal drying practices and poor storage of grain can lead to the growth of micro-toxin producing moulds which produces aflatoxin, a potent carcinogen [40]).

A typical food value chain along with the reasons of food loss and waste at each stage:

TABLE 2
FOOD VALUE CHAIN AND REASONS FOR FWL

Production	Handling & Storage	Processing & packaging	Distribution & marketing	Consumption
Food loss while harvesting	Food lost on farm or off-farm and storage	Food lost during processing at village level or industrial	Food lost during transportation to wholesale or retail markets	Food lost at home or business, including in restaurants
Damage while harvesting	Biological degradation due to poor storage	Edible food sorted out as not fit for processing	Food sorted out due to quality	Purchased food not eaten
Sorting out of crops due to not meeting quality and aesthetics standards	Pest and rodent attacks	Losses during processing like canning and packaging	Food reaching expiry date before being purchased	Food wasted due to large portions
Crops not collected due to poor harvesting or lack in demand	Often caused by inadequate access to modern energy	Often caused by inadequate access to modern energy	Food does not look aesthetically fit although is edible	Food reaching expiry date before being cooked

Source: Adapted from [41]

4.2.3 Critical Post-harvest Loss Points:

It has been established from research and assessment results over the years such that it is now common cause that PHL occur throughout the agricultural chain. Obviously, the quantum differs by stage and by level of sophistication and efforts designed to reduce PHL. The figure (2) below shows where PHL occur in the chain:

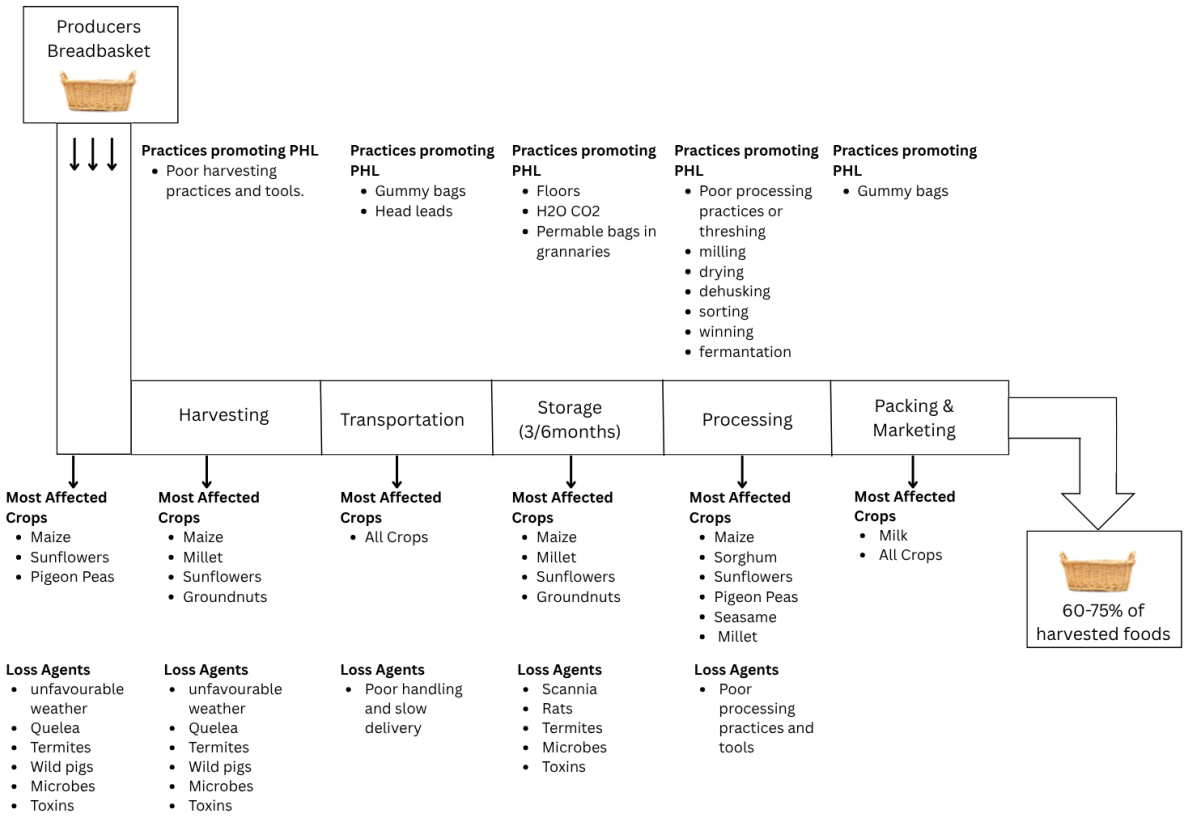

FIGURE 2: Post -harvest throughout the Agricultural Value Chain

Source 42: Presentation by FANRPAN during AU-FAO Post-harvest Regional Workshop, Nairobi, Kenya 24, 25 July 2018

In this review, food and nutrition security is mentioned quite often and therefor it is necessary to describe it. Food and nutrition security is anchored on Four Pillars of (1) Food Availability, (2) Access to Food, (3) Utilisation of Food, (4) Stability of supply of food must exist. See figure 3 below:

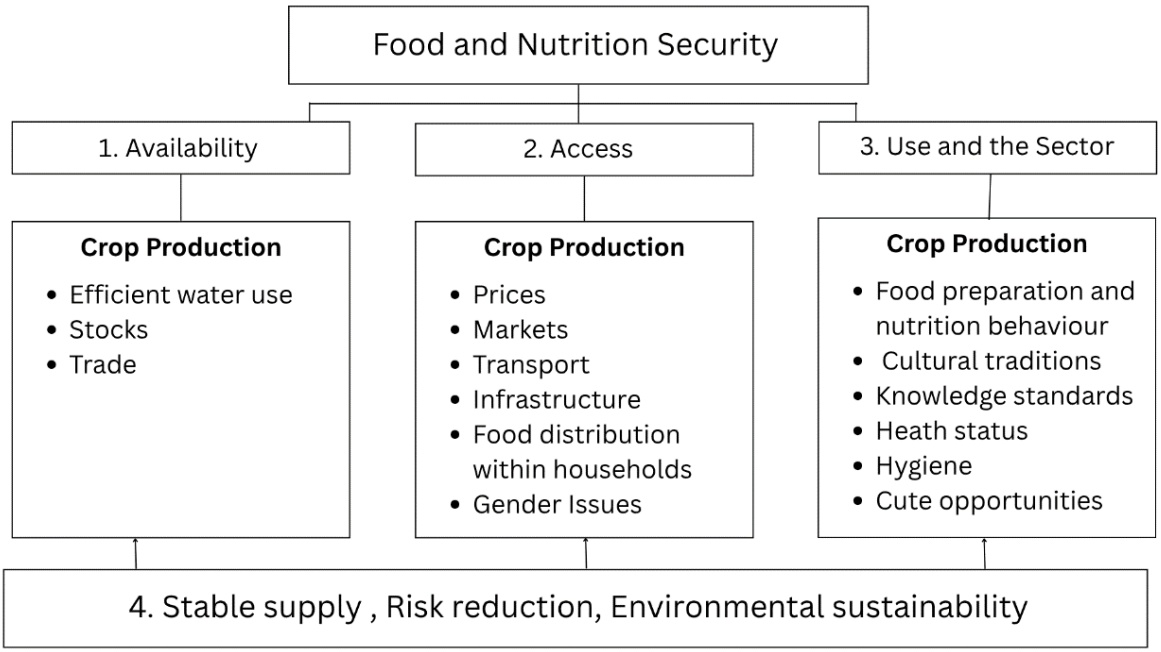

FIGURE 3: The four Pillars of Food and Nutrition Security

Source 43: Adapted from - FAO

Also, as defined PHL occur both in quantitative terms, affecting the food availability pillar of food and nutrition security, and in qualitative terms affecting the food use and utilization pillar as well as the food availability pillars of the food and nutrition security. Apart from reducing the total amount and quality of food available, PHL also exacerbate the already fragile poverty ridden rural economies by eroding income generation along the food value chain and therefore affect the accessibility as well as sustainability pillars of food and nutrition security [43].

4.2.4 Extent of Food Losses and Waste:

The per capita food loss in Europe and North America is 280-300 kilograms per year, in Africa and South/Southeast Asia it is 120-170 kilograms per year [7]. While the per capita production of edible parts of food for human consumption is in Europe and North America about 900 kilograms per year and in Africa and South/Southeast Asia 460 kilograms per year [7]. Per capita food wasted by consumers in Europe and North America is 95-115 kilograms per year and in Africa and South/Southeast Asia is only six to eleven kilograms per year [7].

Food losses in industrialised countries are as high as in developing countries, but in developing countries more than 40% of the food losses occur at post-harvest and processing levels, while in industrialised countries, more than 40% of the food losses occur in retail and consumer levels. Food waste at consumer level in industrialised countries (222 million tonnes) is almost as high as the total net food production in Africa (230 million tonnes).

Reducing PHL is a key pathway to food and nutrition security in Africa. However, knowledge of PHL magnitudes is limited. In 2014 [42] conducted a meta-analysis to expose the nature and magnitude of PHL, and the kinds of interventions that have been attempted to mitigate the losses. Their findings reveal inadequacies of loss assessment methodologies that result in inaccurate PHL estimates [42]. Moreover, losses are often economic rather than physical product losses. Overall, technologies for loss mitigation fail to address dynamics of supply chains. Consequently, rigorous PHL assessment using systematic methodologies, as well as holistic approaches for losses mitigation are in need.

4.3 Energy and Food Losses:

([39]; [45]; [46]; [47] IoMe, 2014; [48]) listed the following as important facts to be considered when discussing PHL:

- Approximately one out of every four calories grown to feed people is not ultimately consumed by humans.
- Food Loss Wastage (FLW) of 1.3 billion tonnes of food results in (a) loss of almost 1.4 billion hectares of land that were used to produce that was not consumed, (b) a global blue water footprint for the agricultural production of food wastage was about 250km^3 in 2007; 3.6 times the blue water footprint of total United States of America consumption, (c) GHG emissions of an estimated at 4.4 giga-tonnes of CO_2 equivalent translating to approximately eight per cent of anthropogenic emissions (if food loss was a country, it would be the third largest emitter after China and the USA), (d) an estimated 38% of total energy consumed by food systems is utilised to produce food that is ultimately never consumed by humans.
- The cold chain is the key to tackling the loss of perishable produce. It is estimated that around a quarter of the total food wastage in developing countries could be eliminated if these countries adopted the same level of refrigeration equipment as that in developed economies.
- The challenge is that in nearly all cases, cooling and refrigeration rely on access to a reliable and affordable source of either electricity or diesel fuel, which are often lacking or virtually non-existent in developing countries, particularly in rural areas where energy security is a significant issue.
- If fifty percent of the food waste generated each year in the USA was anaerobically digested, enough electricity would be generated to power over 2.5 million homes for a year.

Currently, agriculture already uses around eleven percent of the world's land surface for crop production, and accounts for 70% of all water withdrawn from aquifers, rivers and lakes[48]. Additionally, the food system currently accounts for about 30% of the world's total energy consumption and is responsible for about 20% of the GHG emissions [46].

The main drivers of FLW can broadly be divided into two main categories, that is, behavioural and infrastructural [49]. Human behaviour and preferences towards foods having specific aesthetic requirement may lead to food, which is fit for human consumption being wasted[49]. A large proportion of food is wasted in industrialised countries due to the prevalence of strict grading and aesthetic standards and waste due to consumer behaviour [50]. Infrastructural limitation on the other hand lead to food being lost due the non-existent or inefficient infrastructure such as food harvesting, storing and processing technologies but also roads for transportation of food along the value chain[49]. A key component of infrastructural limitation is the post-harvest technologies which include modern or traditional harvesting, processing and storing technologies which facilitate the maintenance of quality (appearance, texture, flavour and nutritive value), the protection of food safety and the reduction of losses (both physical and in market value) between harvest and consumption[50].

4.4 The Economic Consequences of PHL:

The annual value of postharvest cereal grain loss in Africa is estimated to be up to US$4 billion of an annual production of US$27 billion [20]. This figure exceeds the total value of food aid that the continent has received over the past ten years (it equals roughly to the annual value of cereal imports into the continent; it is enough to satisfy annual caloric requirements for at least 48 million people). Yet a one per cent reduction in PHL can be translated into US$40 million annual gains for Africa [20].

The world's increasing population and demand for food, reducing food loss and waste is one of the greatest challenges worldwide [51]. Current estimates point to over one billion tonnes of food is lost and wasted worldwide, though nearly ten percent of the global population is suffering from undernourishment and food insecurity. In Mozambique, for example, about one-quarter of the population suffers from undernourishment and food insecurity [52]. Estimates from FAO point to PHL of maize in Mozambique at about 3.69 to 7.92%, this is less than one fifth of on-farm losses reported by other authors or researchers.

Food production relies on an ecological resource base that is coming under increased pressure and has to support multiple demands [53]. Land area is needed for food production, animal feed, timber and other purposes, often at the expense of natural forest lands. Likewise, aquatic ecosystems and fish stocks have to support a growing fisheries industry, which includes fish feed for aquaculture [54]. The land use sector has to be more productive by making more efficient use of the resources available. Current estimates indicate that approximately 28% of the world's agricultural land area is occupied to produce food that is never consumed by humans [52]. Food loss and waste, through the inefficient and unsustainable handling of food, has impacts on deforestation, ecosystem degradation and natural resource depletion. In addition, each year approximately 35% of global fish and sea food products are either lost or wasted, with a considerable proportion due to discards at catch level [21]. This number is unacceptably high considering that fish stocks and their supporting ecosystems are overexploited and degraded worldwide due to poor governance, management and fishing practices [55].

The natural resources and inputs needed in the process and the actions related to waste disposal all generate GHG emissions that contribute to climate change. These aggregated impacts make food loss and waste a major contributor to climate change, accounting for about eight per cent of total global GHS emissions [56], while undermining both human and ecological capacities to cope with climate change.

Irrespective of the country development status, in terms of volume, most food is lost at the agricultural production stage of the supply chains, although for varying reasons [57]. In industrialised countries, field losses at the production stage reflect economic decisions of the farmer to forgo harvesting due to market conditions or due to non-conformity of the produced food to the grading and aesthetic standards set by the consumers[39]. In developing countries however, field losses at production stage result from poor state of the value chains and infrastructure [39]. Specifically, due to the combination of poor education, farming methods (including improper handling, inefficient harvesting methods and premature harvesting) and infrastructure[49]. Pests, disease, overplanting (often motivated by the uncertainty of the weather) and labour shortages contribute to losses at this stage.

On a per capita basis, more food is wasted in industrialised countries than in developing countries, peaking at 280-300 kilograms per capita per year in Europe and North America and around 120-170 kilogram per capita per year in Africa and

South/Southeast Asia [49]. While fruits and vegetables being highly perishable constitute the largest share of the total food lost by mass, PHL in cereals comprise the largest share by calorific content [39]. In SSA specifically, around 36% of food harvested is lost equating to an average 167 kilogram per capita per year where only seven kilograms are at the consumer level [57].

According to [58], food and nutrition security means, when all people at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for active and healthy life. The majority of studies on PHL have concentrated on looking at the sustainability of food systems as regards to human food and nutrition security and natural resource management ([52]; [59]; [54]; [41]; [60]. Unfortunately, there has not been much research work (systematic and empirical) on the impact of PHL on food prices to inform the global policy and regulatory debate [61]. This encouraged [61] to do research on this in order to bridge this information gap and provide policy-makers and practitioners with insights on potential impacts of food loss and waste reduction on prices at inter- and intra-regional level.

The results showed that reducing PHL can be beneficial in reducing overall food prices, which has differential impacts across producers and consumers in the Western Europe and Africa, for example[61]. In general, Africa experiences welfare losses but these areas are small fraction of the economy. This outcome was the result of different, that is, positive and negative impacts on various actors in the African economies, including impacts on producers as sellers losing out from increased competition from EU food producers [61]. The effects are highest in regions where action is being taken to reduce food loss and waste, that is, the EU thus providing a compelling argument for policy-makers waiting to tackle high food prices to enact plans/actions in their respective regions and/or countries to reduce PHL[54].

The complex interactions between supply and demand shifts arising from PHL reduction illustrate that it is difficult to predict the potential socio-economic impacts of such actions, especially in a world that is continuously and rapidly changing and that trade-offs are likely to occur[61].This provides useful insights into what might happen and provides a useful starting point for further and more complex foresight analysis of what the world may look like now and beyond [61].Work is required in the following areas:

- Food loss and waste should be incorporated explicitly in the modelling of the food system, preferably as endogenous outcomes or activities that have returns and costs, so that underlying causes and measures to tackle food loss and waste, and associated costs can be modelled.
- Short-term impacts maybe analysed by adjusting the model for market rigidities/imperfections that result in more vehement price changes.
- If interested in distributional impacts, the model needs to be adapted to include different types of households to account for differential welfare impacts across net food consumers and net food producers.

A major obstacle in the efforts to achieve PHL mitigation is the lack of clear knowledge of the real magnitudes of losses, which makes it impossible to measure progress against anyloss reduction targets [62]; [63]. Uncertain estimates of PHL, coupled with imprecise understanding of the points in value chains where the losses occur as well as the socio-economic factors for the losses could end in policy errors and sub-optimal choices of mitigation approaches [62]. In the literature, estimates of PHL magnitudes vary widely. Figures between 10-40%, and as high as 50-70% are regularly quoted ([64]; [65]; [66]; [66; [23];[68], often from untraceable sources. Furthermore, many estimates link to datasets collected thirty years ago, and are fragmentary and unconsolidated. Whereas the FAO-World Bank "Missing Food" report [5] made a significant contribution in demonstrating current knowledge on the nature, magnitude, and economic value of PHL for stored grains in Africa, a lot more information is still lacking especially concerning commodities other than cereal grains that are equally important for nutrition and for security. Moreover, the report and several other studies ([64]; [7]; [23]; [68]) also point out that major data gaps do exist on the quantification of PHL in Africa.

4.5 Discussions and Implications of Results/Findings:

4.5.1 Evidence of PHL:

In their meta-analysis, [62], found out that evidence of PHL in Africa is sketchy, and quantitative estimates are often derived from inadequate datasets. It is pragmatic for research to focus on losses at a particular level of the value chain where the loss is considered to be significant and potentially recoverable [62]

The major reason for many unreliable PHL estimates is weak assessment methodologies[64]. Many datasets do not account for the interaction of various loss agents and are single-point measurements which omit influence of exogenous factors such as local food use patterns, practices and coping strategies [62]. The omission of social, cultural, economic and ecological factors in loss assessment could lead to over or under estimation of actual losses [69]; [70]; [5]. Such factors could include level of wealth and vulnerability, awareness and technology exposure, perceptions and attitudes, destination of products, farming systems, agro-climatic conditions and pest prevalence [63]. Variability in accuracy and practical application of different losses assessment methods, also exist depending on the nature of the commodity and the type of loss agents [71]; [72]; [73]; [74]). For some commodities such as fresh produce and fish, there are no reliable methods of evaluating PHL as most methods are often subjective ([75]; [76]).

4.5.2 On-farm storage versus value chain:

Most efforts to assess PHL have targeted smallholder farm-level activities, particularly storage, whereby insect infestations and biological deteriorations are the two factors that strongly attract attention [62]. A reason for the skewed focus toward storage losses is because harvested produce is stored for considerable periods so as to counter erratic production patterns, to speculate on price and to guarantee smooth income tenures [77]. The scope has, however, been limited considering that contributions of other food loss agents including rodents, molds, spillage and pilferage remain untracked [62].

Food consumption trends in developing countries including Africa are undergoing transitions [62]. Rapid urbanization and changes in social and cultural practices have modified food habits of communities [78].Thus, unlike in the past, strategies for managing PHL can no longer concentrate on farm-level activities, ignoring the rest of the post-production chain where value addition also takes place [62]. Sorting and grading losses, for instance, are often very important, especially in markets that thrive in quality. Products that are regarded unfit at one market level could be channeled to lower-end markets or be diverted to alternative uses thereby minimizing the overall economic impact of losses [62]. Some alternative uses like bio-energy generation and animal feed processing can generate employment and incomes or directly support the main PHL reduction investment [63].

4.5.3 Economic, quantity and quality losses:

As part of PHL, quality losses impact on food safety, nutritional value and often economic value as successful markets depend on a consistent supply of good quality produce ([79]; [76]). An overlap between quantity and quality losses exists although many PHL assessments in the past targeted quantity alone [62]. Extremely high-quality losses could translate to 100% quantity loss when entire lots have to be discarded as in the cases of severely insect damaged or aflatoxin-contaminated grains ([80]; [16]). Similarly, in fresh produce, weight loss is physiologically linked to bio-deterioration and therefore loss of quality [79].

A reason why estimation of quality losses is not frequent is complication arising from product seasonally and the extent to which markets are sensitive to quality [62]. For example, when there is low supply of grain, such as during droughts or the periods just before a new harvest, there is hardly any good quality grain on the market so that poor quality grain may sell for a price that is greater than that received for better quality grain during abundant harvest [16]. In many African countries quality standards are not enforced or do not exist and so quality changes may be assessed differently by individual consumers [62]. Findings of the present analysis, nonetheless, indicate that consumers have increasingly become quality conscious ([81]; [82]; [83]) which should raise the perspectives for greater emphasis of quality losses in future PHL research.

4.6 Objectives of Post-harvest Technology:

4.6.1 Some objectives of post-harvest technology [84]:

- Maintenance of food quality, that is, appearance, texture, weight, flavor, nutritive value
- Production of food safety

- Reduction in food losses – between the period of harvesting and consumption by improving harvesting, storage, transportation facilities and marketing policies
- Reduction of food waste – reduce food wastage at consumer level – improving marketing skills, efficient distribution of product. Efficient use of food in household
- Effective management of PHL
- Promotion

4.6.2 Factors affecting Post-harvest Losses:

Primary and secondary factors which affect PHL of food products[85].

Primary factors:

- Mechanical loss: caused by poor handling of produce from harvesting to storage
- Microbial action: caused by micro-organisms like bacteria, fungi, yeasts – fruits and vegetables
- Environmental factors: temperature and relative humidity are two important environmental factors responsible for PHL; (included are physical damage, pathogens, atmospheric composition, light, gravity, rodents and other animals, birds, contamination.

Secondary factors:

- Inadequate harvesting methods
- Incomplete drying before threshing
- Inadequate storage facilities
- Longer shipment
- Lack on market access and policies

4.6.3 Control of Post-harvest Losses [86]:

- Post-harvest loss in fruits and vegetables can be minimized by proper cultural operations, harvesting, transportation, storage and pre and post-harvest treatments
- Interrupted supply of water, for example,causes cracking of carrots, radish, tomato and splitting of outerscales of onions
- Sudden and heavy irrigation at late maturity, results in cracking of water-melons and tomatoes
- Heavy application of nitrogenous fertilisers causes faster tissue deterioration in fruits and vegetables, while essential supply of potassic fertilisers improves the keeping quality of fruits and vegetables.

4.7 Post-harvest Loss Management Strategies:

Reducing food loss and waste presents a key opportunity to improve environmental sustainability and is necessary for achieving inclusive and sustainable food systems [54]. This is emphasized in the 2030 Agenda for Sustainable Development, which sets a global target for food loss and waste reduction. Ensuring that food is handled and consumed more sustainably now and, in the future, requires ambitious and collective global efforts, and transformational change is needed at both the international and individual level [52].

Among the many targets that the African Union Commission was mandated to report on in the Agricultural Review Process is the target to halve the current levels of PHL by the year 2025 under the Malabo Declaration Commitment to ending hunger in Africa by 2025 [43]. In line with this target and with the support from the FAO, the Department of Rural Economy and Agriculture (DREA) of the African Union Commission undertook to support efforts on the continent by developing this, the African Union PHL Management Strategy (PHLMS).

Preventing PHL presents a transformative opportunity to address major drivers of global environmental degradation and loss of biodiversity, while simultaneously helping to achieve food and nutrition security[87].It is unacceptable that natural resources are being depleted and vital ecosystems are degraded to produce food, that is, ultimately never consumed, while seven hundred and ninety-five (795) million people are living in chronic hunger [87].

Developing efficient solutions to reduce PHL and waste lies in the recognition of interlinkages among different stages of the supply chain. In other words, the performance of each actor and cost of activities in upstream segments of the chain could determine the quality of the product further down the food supply chain [3]. For instance, improving on-farm storage facilities to reduce PHL should be coupled with proper strategies and interventions to enhance access to markets [52]. In low-income countries solutions should first and foremost take a producer's perspective, for example, by improving harvest techniques, farmer education, storage facilities and cooling chains[3]. In industrialised nations on the other hand, solutions at the producer and industrial levels would only be marginal [51], if consumer education and appropriate stock management at retail level is not in place. Moreover, government investment on capacity building for agriculture and infrastructure and policy support to facilitate market access for farmers and to provide an enabling environment for private sector investment is a non-negotiable factor that cuts across most measures to reduce PHL [52].

In Australia (1996-99) a study showed that around 37 000 tonnes of bananas were lost every year due to rejection at the pack house because of not meeting customer specifications for sale as fresh fruit [88]. Banana growers started to work with packaging companies, state primary industry departments and retailers to identify the major causes of fruit damage in the supply chain and provide solutions [3]. It was found out that losses occurred due to fruit damage during transportation, storage and handling and in supermarkets due to poor staff handling (inadequate training) and consumer handling (lack of awareness) [52]. As a result of extensive collaboration and coordination, the supply chain became more streamlined [52]. Research led by a major Australian retailer led to the introduction of cluster packing, the development of the six-per-layer carton, absorbent paper for sap control as well as the development of product specifications and systematic quality assurance to monitor fruit outturn at points along the chain and implementation of improved cold chain and processes from harvest through to retail [89].

Through their research [89] concluded that packaging can play an important role by reducing damage in transit and handling or by extending shelf life.

The implementation of these initiatives could be supported through further research and communication activities to highlight the critical links and trade-offs between packaging consumption, protection and containment of food and food waste.

The key challenges facing Africa as regards PHL, include the lack of [43]:

- Awareness and communication on the impact or consequences of PHL
- Awareness of standardized PHL measurement methodologies
- Targeted policies and/or strategies at the national levels on PHL
- Appreciation of the economic value of PHL and its impact on food and nutrition security
- Research and development including lack of evidence-based PHL assessments
- Institutional and organizational arrangements including lack of support for generation and dissemination of PHL best practices and knowledge

- Targeted financing and investment in PHL activities

Based on available information, Table 3 below shows a summary of the status of PHL strategies of five selected African countries [43]:

TABLE 3

SUMMARY OF THE STATUS OF PHL STRATEGIES OF FIVE SELECTED AFRICAN COUNTRIES

Country	Title of the Document	Rationale for PHL management strategy
Ethiopia	Post-harvest loss management strategy in grains in Ethiopia – October 2016	The strategy was developed on the recognition that focus on primary production had tended to overlook and effectively neglect the importance of PHL with available data suggesting annual losses in the vicinity of 15-20% of potential grain production due to poor pre-harvest practices and natural disasters and losses of up to 30% post-harvest due to inappropriate collection, transport, storage, pest control systems in Ethiopia (Ethiopia, 2016 pii).
Kenya	Kenya Strategy for Post-Harvest Loss Reduction 2018-2025	The strategy documents for PHL reduction in Kenya does not state the rationale behind the development of the strategy. The strategy notes in general that agriculture was identified in Kenya's Vision 2030 as a key sector for achieving the envisaged annual economic growth rate. Neither does the Agriculture Sector Development Strategy nor the Food and Nutrition Security Policy nor the National Food Safety Policy (2013) of Kenya specifically, according to the PHL strategy, identify post-harvest loss management as a key constraint to food and security in the country.
Tanzania	National Post-Harvest Loss Management Strategy (2017-2027) – December 2017. Second Draft produced in December 2017 with the support of FAO.	Although the current policy environment is more receptive to the importance of PHL, the agriculture strategies have not paid adequate attention to PHL issues in an effort to increase food and income security (Tanzania 2017 p3).
Zambia	Post-harvest Management Strategy for Zambia (2018-2025) – March 2018. Draft Strategy prepared with the support of FAO and submitted in March 2018 for consideration by FAO.	In its second national agricultural policy released in 2016, Zambia recognized post-harvest losses as one of the main challenges that needs urgent attention (Nkonde et al 2018 p9).
Zimbabwe	Post-harvest management Strategy for Zimbabwe (2017-2025) – March 2018. Draft Strategy prepared with the support of FAO and submitted in March 2018	Zimbabwe currently does not have a standalone policy on Post-harvest loss management. Current policy frameworks include a few policy statements on PHL, particularly of the staple maize commodity (Zimbabwe 2018 p viii).

4.7.1 Overview of PHL in Africa:

Post-harvest loss strategy management is about bringing together all possible forms of approaches across the entire value chain that together contribute to reduced levels of losses occurring during and post harvesting of grains, fruits, vegetables, oilseeds, and all food crops, livestock and fisheries products. A study by [90] concluded that from a policy perspective, targeting PHL interventions to improve post-harvest handling techniques (especially those on the farm) is key to reducing PHL. They also concluded that scaling up these interventions must be based on a better understanding of the true extent of PHL. The use of nationally representative household survey data as a PHL measuring methodology is an important step in the right direction [91]. Besides improved storage and crop protection technologies there was a need for better market access and for higher post-

primary education were crucial for PHL management [91]. These factors as alluded by [91], confirm the multi-dimensional nature of PHL but also the multi-disciplinary nature of management support that is required to deal with PHL.

Some of the major challenges found in relation to PHL management include [91]:

- knowledge of PHL magnitudes which currently is limited;
- inadequacies of loss of assessment methodologies that result in inaccurate PHL estimates
- The issue that losses are often economic rather than physical product losses yet that economic value of PHL is rarely known or calculated and
- Failure to address dynamics of supply chains by most technologies for loss mitigation.

Rigorous PHL assessment using systematic methodologies, as well as holistic approaches for losses mitigation are needed in the African continent [91].

4.7.2 Ending hunger in Africa by 2025:

According to the 2016 Global Hunger Index (GHI) Africa Edition produced by the International Food policy Research Institute, while the level of hunger in all countries across Africa, for which GHI scores could be calculated, has declined since 2000, the level of hunger in many countries remains unacceptably high with only three countries out of 42 African countries with scores that fall into the "low" hunger category, which 28 fall into the "serious" category and five countries have 2016 scores in the "alarming" category. A reduction in PHL, among other strategies to enhance the food and nutrition security in Africa, will go a long way to alleviating the huge hunger problem facing the continent.

By its nature and as revealed in many study works over the years, the target to half the current levels of PHL by 2025 calls for greater understanding and efforts towards the establishment of current levels of PHL in food crops. There is no real agreement at the national level as to the exact level of losses that are being experienced. To that effect, the Malabo Declaration target requires that extensive research and analytical work on PHL estimations be undertaken simply to establish the current levels of PHL against which the target of halving this level of losses can be applied. Other key issues that also emerge with analyzing country level losses include methods of post-harvest assessment and analysis which depend on the authority cited; financial support and investment into post-harvest lose reduction; as well as the political willingness and policy level awareness on PHL[41]

V. CONCLUSION

This research review found out that estimates from [21] suggest that as much as 37% of food produced in Africa is lost between production and consumption. These high estimates have motivated international attention to PHL. Yet interventions typically focus on improving on-farm grain storage techniques for small-scale farmers. The estimates use extrapolation from purposively sampled (and often older) case studies that may focus on areas where PHL is largest[94]. More and better quantification of (on-farm) grain loss is needed (which can then be compared with the costs of improved post-harvest practices). Also needed is a better understanding of farmers' behaviour in adopting improved post-harvest technologies.

Globally, energy in agriculture has concentrated on increasing food production (95% of research over the last fifty years was focused on improving production. A paltry 5% was directed to research on reduction of PHL. The consequences for this has been the loss and wasted food to the tune of 1.3 billion metric tonnes per year, worldwide. This is enough to feed 1.6 billion people annually. The cost of this is about US$2.6 trillion per year. To this add the ethical and environmental costs which are difficult to quantify.

PHL contribute to high food prices by removing part of the food from the supply chain. Although food availability and accessibility can be increased by upping production, improving distribution and reducing the losses. However, production resources including land, water and energy are limited and inelastic.

A major obstacle in achieving PHL mitigation is the lack of clear understanding of the real magnitude of PHL, which makes it impossible to measure progress against any loss reduction goals. Uncertain estimates of PHL, coupled with imprecise understanding of the points in value chains where the losses occur as well as the socio-economic factors for the losses could end in policy errors and sub-optimal choices of mitigation approaches.

VI. RECOMMENDATIONS

There are several implications for policymakers, farmer organisations and agricultural industries. First, policy makers might rethink the net social welfare impact of PHL and be very methodical when assessing the causes. The opportunity costs of mitigating loss appear to be a third critical component to causes, in addition to uncontrollable events and technical inadequacies. Second, policy goals of fixed levels of PHL may be unrealistic without a proper understanding of the management context facing farmers, especially a system of production that includes multiple cropping.

Below are a brief summary of recommendations to be taken note of:

- Reducing PHL presents a cost-effective opportunity to improve resource efficiency in the food system and help mitigate the risks of natural resource depletion. In addition, reducing PHL would ensure more sustainable use of resources thereby putting less pressure on ecosystems, including soils and water.
- Addressing fish losses and waste, including discards is necessary to reduce the impacts of fisheries on aquatic ecosystems.
- Food losses in low-income countries are often connected to the lack of access to energy, particularly in the post-harvest phase. In order to make the transition towards sustainable food value chains that reduce both food losses and fossil fuel dependence in food systems, it is necessary to upscale clean or low-carbon technologies. Increased deployment of the technologies that use renewable energy would improve the sustainability of food systems, while reducing losses in developing countries.
- Efforts that reduce PHL of food are essential to enhance global climate action because of their collective contributions to three overall objectives: mitigating climate change by reducing GHG emissions associated with PHL; strengthening resilience to cope with climate change and increasing net production output; PHL reduction measures, in the contest of resilient and low-emission food systems, should therefore be integrated into climate change strategies and action plans as additional opportunities towards achieving mitigation and adaptation objectives.
- Reducing the amount of food that is lost or wasted calls for harmonized policies and integrated food system approaches that consider all risks, challenges, opportunities and potential trade-offs. Creating an enabling environment requires a re-examination of existing policies and regulatory frameworks, including incentive schemes. Identifying policy gaps and ensuring policy coherence across sectors is key to inclusive pleasing processes for addressing the drivers and underlying causes of PHL.
- Bringing together governments, food producers and investors can help identify challenges and opportunities for addressing inefficiencies in food systems and accelerate the deployment of sustainable technologies in food value chains. Combining such efforts with sustainable practices and consumption patterns can pave way towards safeguarding environmental resources and ultimately needing the goals and targets set out in the 2030 Agenda for Sustainable Development. Emphasis must be targeted at improving access to finance, while encouraging appropriate policy incentives and building management capacities.

For the future of food in Africa the following are recommended [20] and [21]:

- Food production will have to increase by 60%, while adapting to climate change
- 80% of the necessary production increases must come from intensification and not from opening up new land.
- 70% of African population will live in urban centres; extending food value chains
- Loss reduction can be a more resource efficient response to food shortage than increased production.
- Silver lands of Zambia are working with smallholder farmer communities to help provide grain storage facilities (silos). They reckon that in Sub-Saharan Africa, around 30% of food is lost during handling and storage, this is compared to six per cent in North America. Poor storage facilities force farmers to often sell at hardest time when prices are at their lowest thus eroding their returns. Providing key storage infrastructure is essential to prevent PHL and ensure supply of quality grains.

VII. ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Human and Animal Rights

No animal/humans were used for studies that are base of this research.

Consent for Publication

Not applicable.

CONFLICT OF INTEREST

The author (Douglas Ncube PhD) certify that he has no affiliations with or involvement in any organisation or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership; employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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