Technical paper ● Scientific & Technical Department

POST-HARVEST LOSSES AND STRATEGIES TO REDUCE THEM

By Victor Kiaya

ACF **January 2014**

LEGAL INFORMATION

Statement on Copyright

Non responsibility clause

This document provides public access to information concerning the actions and policies of ACF International. Our objective is to disseminate information that is accurate and up-to date on the day it was initiated. We will make every effort to correct any errors that are brought to our attention. However, ACF bears no responsibility for information contained in this document.

This information:

- Is solely intended as general information and does not focus on the particular situation of any physical person, or person holding any specific moral opinion;
- Is not necessary complete, exhaustive, exact or up-to-date;
- Sometimes refers to external documents or sites over which ACF has no control and for which ACF declines all responsibility;
- Does not constitute legal advice.

The present non-responsibility clause is not aimed at limiting ACF's responsibility contrary to requirements of applicable national legislation, or at denying responsibility in cases where this cannot be done in view of the same legislation.

Introduction

Today, one of the main global challenges is how to ensure food security for a world growing population whilst ensuring long-term sustainable development. According to the FAO, food production will need to grow by 70% to feed world population which will reach 9 billion by 2050.. Further trends like increasing urban population, shift of lifestyle and diet patterns of the rising middle class in emerging economies along with climate change put considerable pressure strain on the planet's resources: declining freshwater resources and biodiversity, loss of fertile land, etc. Consequently, there is a need for an integrated and innovative approach to the global effort of ensuring sustainable food production and consumption (Nellemann et al., 2009; World Economic Forum 2009; FAO/OECD, 2011; Foresight, 2011; EU ERA-NET SUSFOOD 2012-2014).

In the meantime, while the number of food insecure population remains unacceptably high (FAO, 2010; IFAD, WFP and FAO, 2012), each year and worldwide, massive quantities of food are lost due to spoilage and infestations on the journey to consumers (FAO, 2011; Stuart, 2009; FAO, 2002). In some African, Caribbean and Pacific ACP countries, where tropical weather and poorly developed infrastructure contribute to the problem, wastage can regularly be as high as 40-50% (SPORE, 2011). Obviously, one of the major ways of strengthening food security is by reducing these losses.

Along the renewed focus on investment in agriculture that began in 2008, there is an increasing interest in effective intervention for Post-Harvest Losses (PHL) reduction. The investment required to reduce PHL is relatively modest and the return on that investment rises rapidly as the price of the commodity increases.

Action Contre la Faim (ACF) gives a particular attention to PHL reduction. During a research prioritization exercise undertaken by ACF Food Security and Livelihoods sector (FSL) in 2011, postharvest handling was recognized as one of the important areas requiring attention. It is of high importance in the effort to combat hunger, raise income and improve food security and livelihoods in the areas where ACF intervenes. In view of this, it was decided to develop a brief technical paper on postharvest losses and strategy to reduce them.

The term "postharvest loss" - PHL refers to measurable quantitative and qualitative food loss in the postharvest system (de Lucia and Assennato, 1994). This system comprises interconnected activities from the time of harvest through crop processing, marketing and food preparation, to the final decision by the consumer to eat or discard the food.

Nowadays, interventions in PHL reduction are seen as an important component of the efforts of many agencies to reduce food insecurity. PHL is increasingly recognized as part of an integrated approach to realizing agriculture's full potential to meet the world's increasing food and energy needs. Therefore, reducing PHL along with making more effective uses of today's crops, improving productivity on existing farmland, and sustainably bringing additional acreage into production is critical to facing the challenge of feeding and increased world population.

It is, however, evident for ACF that postharvest and value addition are integral components of strategies to improve agricultural productivity and linkages between farmers and markets

which will help contribute to food security and economic development of its target population.

This technical paper highlights some concepts and problems of postharvest food losses in cereals and perishable crops, and critical factors governing PHL and food waste. It covers losses occurring along the entire food chain, and highlights some strategies and alternatives ways of preventing and reducing these losses. The paper has a special focus on less developed countries where ACF missions intervene.

1. Few definitions and concepts

1.1 What is postharvest loss?

Postharvest loss can be defined as the degradation in both quantity and quality of a food production from harvest to consumption. Quality losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product. These losses are generally more common in developed countries (Kader, 2002). Quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries (Kitinoja and Gorny, 2010). A recent FAO report indicates that at global level, volumes of lost and wasted food in high income regions are higher in downstream phases of the food chain, but just the opposite in low-income regions where more food is lost and wasted in upstream phases (FAO, 2013).
Why ACF is concerned about PHL?

Farmers and food sellers have been concerned about losses since agriculture began. Yet the problem of how much food is lost after harvest to processing, spoilage, insects and rodents, or to other factors takes on greater importance as world food demand grows. Cutting postharvest losses could, presumably, add a sizable quantity to the global food supply, thus reducing the need to intensify production in the future.

1.2 Agricultural crops losses

Losses are a measurable reduction in foodstuffs and may affect either quantity or quality (Tyler and Gilman, 1979). They arise from the fact that freshly harvested agricultural produce is a living thing that breathes and undergoes changes during postharvest handling.
Loss should not be confused with damage, which is the visible sign of deterioration, for example, chewed grain and can only be partial. Damage restricts the use of a product, whereas loss makes its use impossible. Losses of quantity (weight or volume) and quality (altered physical condition or characteristics) can occur at any stage in the postharvest chain (Fig 1).

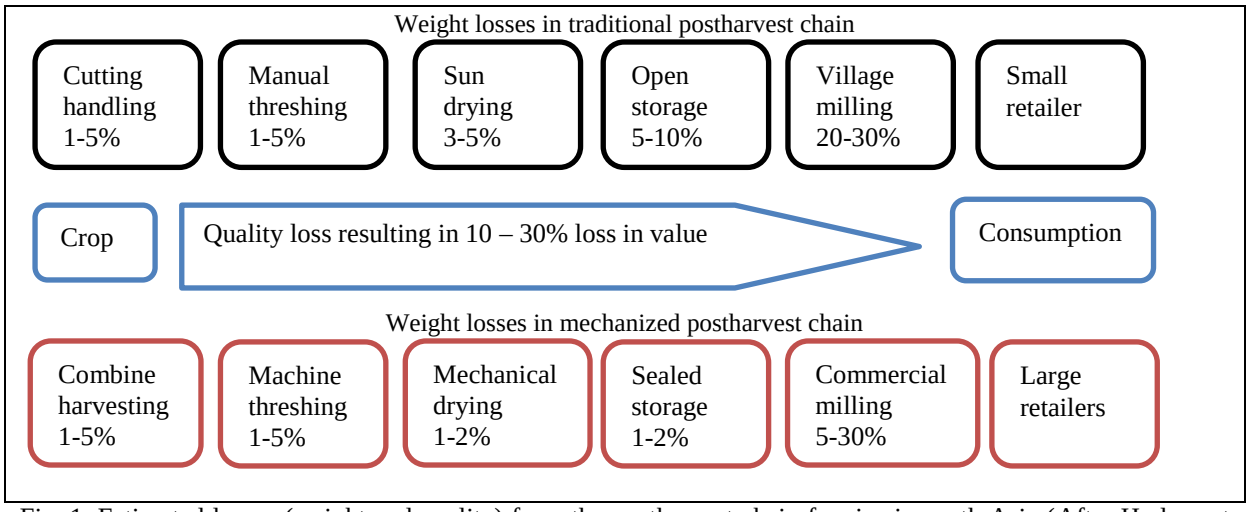


Fig. 1. Estimated losses (weight and quality) from the postharvest chain for rice in south Asia (After Hodges et al. 2011)

Economic loss can also occur if the produce is subsequently restricted to a lower value market. Here, food loss is a subset of PHL and represents the part of the edible share of food that is available for consumption at either the retail or consumer levels but not consumed for any reason.

1.3 Food Losses and Food Waste

Food losses refer to the decrease in edible food mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption (FAO, 2013). Food losses take place at production, postharvest and processing stages in the food supply chain (Parfitt et al., 2010). Food losses are mainly due to poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack to markets.

Food waste refers to food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil. Food waste occurs at the food chain (retail and final consumption) and relates to retailers' and consumers' behaviour.

Food wastage refers to any food lost by deterioration or waste. The term "wastage" includes both food loss and food waste

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. As defined by Hodges et al. (2011), *"food waste is the subset of food loss that is potentially recoverable for human consumption"*. Therefore, food that was originally meant to human consumption but which fortuity gets out the human food chain is considered as food loss or waste even it is then directed to a non-food use (feed, bioenergy, etc.). This approach distinguishes "planned non-food uses and "unplanned" non-food uses, which are hereby accounted under losses (FAO, 2011).

Table 1: Generic food supply chain and examples of food waste (Parfitt et al., 2010)

Stage	Examples of waste
1. Harvesting, handling at harvesting	*Edible crops left in field, ploughed into soil, eaten by pests; timing of harvest not optimal; crop damaged during harvesting*
2. Threshing	*Loss due to poor technique*
3. Drying, transport and distribution	*Quality and quantity loss of during drying, poor transport infrastructure; loss owning to spoiling/bruising*
4. Storage	*Pests and disease attacks, spillage, contamination; natural drying out of food*
5. Primary processing, cleaning, classification, hulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, milling	*Process losses; contamination in process causing loss of quality.*
6. Secondary processing, mixing, cooking, frying, molding, cutting, extrusion	*Process losses; contamination in process causing loss of quality*
7. Product evaluation and quality control	*Product disregarded /out-grades in supply chain*
8. Packaging	*Inappropriate packaging damages produces; grain spillage from sacks; attack by pests*
9. Marketing, selling, distribution	*Damage during transport; spoilage; poor handling; losses caused by poor storage*
10. Post-consumer	*Poor storage/stock management; discarded before serving; poor food preparation; expiration*
11. End of life disposal of food waste/loss at different stages in supply chain.	*Food waste discarded may be separately treated, fed to animals, mixed with other wastes/landfilled*

Key facts and figures on food waste and losses per continent are described below (Nellemann et al., 2009):

Australia: In a survey of more than 1,600 households in Australia in 2004 on behalf of the Australia Institute, it was concluded that on a country-wide basis, $10.5 billion was spent on items that were never used or thrown away. This amounts to more than $5,000/ capita/year.

Asia: Losses for cereals and oil seeds are lower, about 10-12%, according to the Food Corporation of India. Some 23 million tonnes of food cereals, 12 million tonnes of fruits and 21 million tonnes of vegetables are lost each year, with a total estimated value of 240 billion Rupees. A recent estimate by the Ministry of Food Processing is that agricultural produce worth 580 billion Rupees is wasted in India each year (Lundqvist et al., 2008).

Africa: In many African countries, the post-harvest losses of food cereals are estimated at 25% of the total crop harvested. For some crops such as fruits, vegetables and root crops, being less hardy than cereals, post-harvest losses can reach 50% (Voices Newsletter, 2006). In East Africa and the Near East, economic losses in the dairy sector due to spoilage and waste could average as much as US$90 million/year (FAO, 2004). In Kenya, each year around 95 million litres of milk, worth around US$22.4 million, are lost. Cumulative losses in Tanzania amount to about 59.5 million litres of milk each year, over 16% of total dairy production during the dry season and 25% in the wet season. In Uganda, approximately 27% of all milk produced is lost, equivalent to US$23 million/year (FAO, 2004).

Europe: United Kingdom households waste an estimated 6.7 million tonnes of food every year, around one third of the 21.7 million tonnes purchased. This means that approximately 32% of all food purchased per year is not eaten. Most of this (5.9 million tonnes or 88%) is currently collected by local authorities. Most of the food waste (4.1 million tonnes or 61%) is avoidable and could have been eaten had it been better managed (WRAP, 2008; Knight and Davis, 2007).

United States of America: In the United States 30% of all food, worth US$48.3 billion (€32.5 billion), is thrown away each year. It is estimated that about half of the water used to produce this food also goes to waste, since agriculture is the largest human use of water. Losses at the farm level are probably about 15-35%, depending on the industry. The retail sector has comparatively high rates of loss of about 26%, while supermarkets, surprisingly, only lose about 1%. Overall, losses amount to around US$90 billion-US$100 billion a year (Lundqvist et al., 2008).

2. Main elements of the postharvest system <case of non-perishable food crops>

2.1 Harvesting

The time of harvesting is determined by the degree of maturity. With cereals and pulses, a distinction should be made between maturity of stalks (straw), ears or seedpods and seeds, for all that affects successive operations, particularly storage and preservation.

2.2 Pre-harvest drying (mainly for cereals and pulses)

Extended pre-harvest field drying ensures good preservation but also increases the risk of loss due to attacks by pests (birds, rodents, and insects) and moulds not to mention theft. On the other hand, harvesting before maturity entails the risk of loss through mould development leading to the decay of seeds.

2.3 Transport

Much care is needed in transporting a really mature harvest, in order to prevent detached grain from falling on the road before reaching the storage or threshing place. Collection and initial transport of the harvest thus depend on the place and conditions where it is to be stored, especially with a view to threshing.

2.4 Post-Harvest drying

The length of time needed for full drying of ears and grains depends considerably on weather and atmospheric conditions. In structures for lengthy drying such as cribs, or even unroofed threshing floors or terraces, the harvest is exposed to wandering livestock and the depredations of birds, rodents or small ruminants. Apart from the actual wastage, the droppings left by these 'marauders' often result in higher losses than what they actually eat. On the other hand, if grain is not dry enough, it becomes vulnerable to mould and can rot during storage.

Moreover, if grain is too dry it becomes brittle and can crack after threshing, during hulling or milling, especially for rice if milling takes place longer time (two to three months) after the grain has matured, thus causing heavy losses. During winnowing, broken grain can be removed with the husks and is also more susceptible to certain insects (e.g. flour beetles and weevils). Lastly, if grain is too dry, this means a loss of weight and hence a loss of money at the time of sale.

2.5 Threshing

If a harvest is threshed before it is dry enough, this operation will most probably be incomplete. Furthermore, if grain is threshed when it is too damp and then immediately heaped up or stored (in a granary or bags), it will be much more susceptible to attack by micro-organisms, thus limiting its conservation.

2.6 Storage

Storage is the art of keeping the quality of agricultural materials and preventing them from deterioration for specific period of time, beyond their normal shelf life. Different crops are harvested and stored by various means depending on the end utilization. Whether the seed will be used for new plantings the following year, for forage being processed into livestock feed, or even for crops to be developed for a special use, the grower must be aware of harvesting and storage requirements toward a quality product. After determining the prescribed use for the crop, timing for harvest and storage is of important consideration. Along with an assessment of when to harvest, the farmer needs to determine the method of harvesting.

There are a wide range of storage structures used throughout the world to successfully store horticultural produce. In general the structure needs to be kept cool (refrigerated, or at least ventilated and shaded) and the produce put into storage must be of high initial quality.

Storage is essential for the following reasons:
- Perishable nature of agric. & bio-materials
- Provision of food materials all year round
- Pilling/ provision for large scale processing
- Preservation of nutritional quality
- Price control and regulation
- Optimization of farmers' gain / financial empowerment of farmers
- Opportunity for export market, etc

2.7 Processing

Excessive hulling or threshing can also result in grain losses, particularly in the case of rice (hulling) which can suffer cracks and lesions. The grain is then not only worth less, but also becomes vulnerable to insects such as the rice moth (*Corcyra cephalonica*).

2.8 Marketing

Marketing is the final and decisive element in the post-harvest system, although it can occur at various points in the agro-food chain, particularly at some stage in processing. Moreover, it cannot be separated from transport, which is an essential link in the system.

Table 2: Comparison between properties of non-perishable (mainly cereals) and perishable (roots and tubers) regarding their storage capacity (Source: FAO, 1984, quoted by Knoth, J., 1993)

Non-perishable food crops	Perishable food crops
Harvest manly seasonal, need for storage of long duration	Possibility of permanent or semi-permanent production, needs for short-term storage
Preliminary treatment (except threshing) of the crop before storage exceptional	Processing in dried products as an alternative of the shortage of fresh products
Products with low level of moisture content (10-15 percent or even less)	Products with high level of moisture in general between 50-80 percent
Small "fruits" of less than 1 g	Voluminous and heavy fruits from 5 g to 5 kg or even more
Respiratory activity very low of the stored product, heat limited	High or even very high respiratory activity of stored products inducing a heat emission in particular in tropical climates
Hard tissues, good protection against injuries	Soft tissues, highly vulnerable
Good natural disposition for storage even for several years	Products easily perishable, natural disposition for storage between some weeks up to several months (strong influence of the varieties)
Losses during storage mainly due to exogenous factors (moisture, insects or rodents)	Losses due partly to endogenous factors (respiration, transpiration, germination) and partly to exogenous factors (rot, insects)

3. Critical factors contributing to postharvest loss

Postharvest losses vary greatly among commodities and production areas and seasons.
As a product moves in the postharvest chain, PHLs may occur from a number of causes, such as improper handling or biodeterioration by microorganisms, insects, rodents or birds. An important factor in developed countries is that a large amount of the food produced is not eaten but discarded, for reasons such as it was left on the plate after a meal or it passed its expiry date. In contrast, failure to consume available food in Less Developed Countries (LDCs) is not a reported concern; instead the low-quality food remaining in markets at the end of the day is sustenance for the very poor. The issue in LDCs is inefficient postharvest agricultural systems that lead to a loss of food that people would otherwise eat, sell or barter

to improve their livelihoods (Hodges et al., 2010). There are internal and external factors contributing to postharvest loss.

3.1 Internal Factors

The following sections describe PHL occurring at all stages in the food supply chain from the moment of harvesting, to handling, storage, processing and marketing.

3.1.1 Harvesting

The time of harvesting is determined by degree of crop maturity and weather conditions. Primary causes of losses at the harvest stage include:

- Absence of an established maturity index[1] for some commodities, and/or lack of maturity index for local export markets.

- Low adoption of established indices, as price and distance to market influence adoption.

- Poor weather at harvesting time which affects the operations and functionality of harvesting machines or human labor and usually increases the moisture content of the harvested products.

NB. Loss is also caused by employment of improper harvesting methods such as: Rough handling; untimely harvesting; lack of appropriate and/or poorly-designed harvesting tools, equipment, and harvesting containers.

3.1.2 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.

3.1.3 Transportation

Primary challenges in the transportation stage of the supply chain include poor infrastructure (roads, bridges, etc.), lack of appropriate transport systems, and a lack of refrigerated transport. In most developing countries, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes of transport, especially those suitable for perishable crops, are not widely available. This is true both for local marketing and export to other countries. Most producers have small holdings and cannot afford to purchase their transport vehicles. In a few cases, marketing organizations and cooperatives have been able to acquire transport vehicles but cannot alleviate poor road conditions (Kader, 2002).

3.1.4 Storage

[1] Maturity Index: for a commodity is a measurement or measurements that can be used to determine whether a particular commodity is mature.

Facilities, hygiene, and monitoring must all be adequate for effective, long-term storage. In closed structures (granaries, warehouses, hermetic bins, silos), control of cleanliness, temperature, and humidity is particularly important. It also very important to manage pests and diseases since damage caused by pests (insects, rodents) and molds can lead to deterioration of facilities (e.g. mites in wooden posts) and result in losses in quality and food value as well as quantity.

3.1.5 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: lack of national standards and poor enforcement of standards, lack of skill, awareness, and financial resources.

3.1.6 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 sold in an unpackaged form or is tied in bundles. This type of market handling of fresh produce greatly reduces its shelf life if it is not sold quickly.

3.1.7 Secondary processing

Causes of post-harvest loss in this stage include limited availability of suitable varieties for processing, lack of appropriate processing technologies, inadequate commercialization of new technologies and lack of basic infrastructure, inadequate facilities and infrastructure, and insufficient promotion of processed products.

3.1.8 Biological

Biological causes of deterioration include respiration rate, ethylene production and action, rates of compositional changes (associated with color, texture, flavour, and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. 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. All these factors have been discussed by numerous authors (Kitimoja and Gorny, 1999; Kader, 2002; Gross et al, 2002).

3.1.9 Microbiological

Micro-organisms cause damage to stored foods (e.g., 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..

3.1.10 Chemical

Many of the chemical constituents naturally present in stored foods spontaneously react causing loses of colour, flavour, texture and nutritional value. One such reaction is the "*maillard relation'* that causes browning and decolouration in dried fruits and other product. There can also be harmful chemicals such as pesticides or obnoxious chemical such as lubricating oil (Atanda et al., 2011).

3.2 External Factors

Factors outside of the food supply chain can cause significant postharvest loss. These factors can be grouped into two primary categories: environmental factors ic and socio-economic patterns and trends.

3.2.1 Environmental factors

Climatic conditions, including wind, humidity, rainfall, and temperature influence both the quantity and quality of a harvest (Grolleaud 2002).

a) Temperature

In general, the higher the temperature the shorter the storage life of horticultural products and the greater the amount of loss within a given time, as most factors that destroy the produce or lower its quality occur at a faster rate as the temperature increases (Atanda et al. 2011).

b) Humidity

There is movement of water vapour between stored food and its surrounding atmosphere until equilibrium of water activity in the food and the atmosphere. 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 adsorbing moisture to the point where mold growth occurs (Atanda et al. 2011).

c) 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°C (Atanda et al. 2011) for each kilometre 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 (FAO, 1983).

d) 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.

3.2.2 Socio-economic factors

Social trend such as urbanization has driven more and more people from rural area to large cities, resulting in a high demand for food products at urban centres, increasing the need for more efficient and extended food supply chains (Parfitt et al. 2010).Other socio-economic factors are linked with grain importation which can introduce new insect species, hence posing a very significant problem. Not only is the imported grain at risk, but the native grain as well. For example, in 1980, the introduction of a new insect species to Africa along with grain importation created weight losses of up to 30% in just 3-6 months of storage (Boxall 2001).

3.3 Critical factors governing PHL and waste in developed and less developed countries

3.3.1 Developed countries

Developed countries have extensive and effective cold chain systems ensuring prolonged product shelf-life. Additionally, more sophisticated management and new technologies continue to improve the efficiency with which food is brought into stores, displayed and sold. A key factor in PHL is growing consumer intolerance of substandard foods (e.g. too small) or cosmetic defects such as blemishes and misshapen produce, and this has increased the rejection rate. For example, grading to satisfy the demand for greater product specifications has led to waste for some products (Hodges et al., 2010).

3.3.2 Less developed countries

In Less Developed Countries (LDCs), the main cause of loss is biological spoilage. Livestock products, fish, fruit and vegetables lose value very quickly without refrigeration. In contrast, roots, tubers and grain products are less perishable as they have lower moisture contents, but poor post-harvest handling can lead to both weight and quality losses. Cereal grain products are least susceptible to PHL, but grain may be scattered, dispersed or crushed during handling. They may also be subject to biodeterioration (Grolleaud 1997; Boxall 2002) that may start as cereal crops reach physiological maturity. Weather is a key issue at harvest. In developing countries with hot climates, most small-holder farmers rely on sun drying to ensure that crops are well dried before storage. If unfavourable weather conditions prevent crops from drying sufficiently, then losses will be high.

The causes of food losses and waste in low-income countries are mainly connected to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging and marketing systems. Given that many smallholder farmers in developing countries live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods.

4. Technologies and practices to reduce post-harvest losses

There are many examples of promising practices. These range from training in improved handling and storage hygiene to the use of hermetically sealed bags and household metallic silos, and are supported by enhancing the technical capabilities of local tinsmiths in silo construction. (The World Bank et al., 2011).

The choice of technology package depends on circumstances, such as the scale of production, crop type, prevailing climatic conditions, and the farmers' affordability and willingness to pay (which are linked to social, cultural and economic implications of adoption).

Some strategies for reducing postharvest losses are listed below:

1. Simple and basic strategy of reducing post-harvest food losses for any type of commodity.

A systematic analysis of each commodity production and handling system is the logical first step in identifying an appropriate strategy for reducing postharvest losses (Bell et al., 1999; Kitinoja and Gorny, 1999).

2. Strategies of reducing post-harvest food losses in cereal grains

Stage in the food system	**Description and strategy**
Harvesting	In tropical countries in general, most grains have a single annual harvesting season, although in bimodal rainfall areas there may be two harvests (e.g., Ghana and Uganda). African producers harvest grain crops once the grain reaches physiological maturity (moisture content is 20-30%) (FAO, World Bank, 2011). At this stage the grain is very susceptible to pest attacks. Poor farmers sometimes harvest crops too early due to food deficiency or the desperate need for cash. In this way, the food incurs a loss in nutritional and economic value, and may get wasted if it is not suitable for consumption. Quality cannot be improved after harvest, only maintained; therefore, it is important to harvest at the proper maturity stage and at peak quality.
Drying	Most farmers in Africa, both small and large, rely almost exclusively on natural drying of crops by combining sunshine and movement of atmospheric air through the product; consequently, damp weather at harvest time can be a serious cause of postharvest losses (De Lima, 1982). Grains should be dried in such a manner that damage to the grain is minimized and moisture levels are lower than those required to support mold growth during storage (usually below 13-15%). This is necessary to prevent further growth of fungal species that may be present on fresh grains. The harvested crop may be dried in the yard or in a crib as indicated in figures A and B.
Threshing/shelling	For some grains, particularly millet and sorghum, threshing may be delayed for several months after harvest and the unthreshed crop stored in open cribs. In the case of maize, the grain may be stored on the cob with or without sheathing leaves for some months, or the cobs may be shelled and grain stored. Some machinery suitable for small small-scale operation exists such as: maize shellers; Rice mechanical threshers which are actively being promoted by the International Rice Research Institute (IRRI). See figure C.

Winnow/cleaning	Usually done prior to storage or marketing if the grain is to be sold directly. For the majority of the smallholder , this process is done manually. It is relatively ineffective from a commercial perspective, since grain purchased from smallholders frequently requires screening to remove stones, sand, and extraneous organic matter. There is little incentive for smallholders to provide well-cleaned grain for marketing; as a result profits from sales are limited. See figure D.
On-farm storage	Post-harvest losses at storage are associated with both poor storage conditions and lack of storage capacity. It is important that stores be constructed in such a way as to provide: -dry, well-vented conditions allowing further drying in case of limited opportunities for complete drying prior to storage; -protection from rain and drainage of ground water; and -protection from entry of rodents and birds and minimum temperature fluctuations.

Fig A. Maize drying in the yard.

Source: Rick Hodges in missing food, 2011.

Fig B. Maize drying in a crib

Fig C. Thresher (source Victor; ACF Aceh 2006).

Fig D. Winnowing (source Rick, H.; 2011)

3. Strategies of reducing post-harvest food losses in perishable crops (roots and tubers)

Root and tuber crops are still living organisms after they have been harvested and losses that occur during storage arise mainly from their physical and physiological condition. The main causes of loss are associated with mechanical damage, physiological condition (maturity, respiration, water loss, sprouting), diseases and pests. To ensure effective storage of root and tuber crops, these major causative factors need to be properly understood and, where appropriate, be properly controlled, taking into account the socio-economic factors which prevail in the areas of production and marketing (FAO, 1985).

Stage in the food system	**Description and strategy**
Harvesting	It is the most important phase.. Unless this operation is carried out with maximum efficiency, later prevention of food loss activities may be a waste of time. If, for example, roots and tubers are bruised or otherwise damaged during harvesting, consideration of improved handling or packaging is not likely to be worthwhile, since an early infestation with moulds and virus will occur and rotting will have started. If harvesting operations are correctly undertaken there is greater scope for later introduction of improved methods. Provision of the proper tools and equipment for harvesting and training workers in their correct use should be a priority prevention of food loss activity.
Handling	The skin of roots and tubers is an effective barrier to most of the opportunistic bacteria and fungi that cause rotting of the tissues. Breaking of the skin also stimulates physiological deterioration and dehydration. Careful digging and movement of roots and tubers significantly reduces post harvest losses.
Packing	Packing of the roots is usually done in the field. Farmers commonly pack the roots and strategically place the large roots

	at the top on the bag to quickly attract the buyer on first sight. Packing should minimize deterioration of the roots within the container and cushion against impact and compression. During packing in the field care must be taken to minimise physical damage that results from impact bruises due to stacking and overfilling of bags, abrasion or vibration bruises due to root movement against each other. Therefore packages should be neither loose (to avoid vibration bruising during transport) nor overfilled, and should provide good aeration.
Transportation	Temperature management is critical during long distance transport, so loads must be stacked to enable proper air circulation to carry away heat from the produce itself as well as incoming heat from the atmosphere and off the road. In many developing countries traditional baskets and various types of trays or buckets are used for transporting produce to the house or to village markets. These are usually of low cost, made from readily available material and serve the purpose for transport over short distances. But, they have many disadvantages in large loads carried over long distances (i.e. they are difficult to clean when contaminated with decay organisms). However, packaging can be a major item of expense in produce marketing, especially in developing countries where packaging industries are not well developed. The selection of suitable containers for commercial scale marketing requires very careful consideration. Among the various types of packaging material that are available: natural and synthetic fibre sacks and bags as well as moulded plastic boxes seem to be more suitable and have greater promise for packaging roots and tubers and for their transport to distant markets.
Storage	The following three things must be done to ensure successful storage of fresh roots and tubers. i) Carefully select only top quality roots and tubers without any signs of handling or pest or disease damage for storage; ii) keep them in specially designed stores and iii) check the stores at regular intervals. Many farmers do not routinely store fresh roots and tubers, but leave them in the ground until required. It is possible to store fresh roots successfully in specially constructed pits or in mounds, or clamp stores. For example, when storing potatoes, a field storage clamp is a low cost technology that can be designed using locally available materials for ventilation and insulation.
Processing	Root and tuber crops (cassava, sweet potato, yam etc…) are both important household food security and income generating crops in many developing countries. Overcoming the perishability of the crops, improving marketing, enhancing nutritional value and adding economic value through processing are the main strategic areas in for reducing postharvest losses. The various processing techniques are listed below: peeling and washing, grating, pressing/fermentation,

	sieving, frying/drying. All these techniques can be divided into: Traditional methods such as drying (production of dehydrated chips); processing into 'gari' and farinha de mandioca; production of bread; production of 'attieke'. Improved methods of production of dehydrated chips such as: simple processing machinery developed by the International Potato Center "CIP" (washer, peeler, slicer and dryer). An important aspect of processing is that it is often intended to prolong the preservation period of a product under ambient conditions. The most appropriate products in this respect are dehydrated root and tubers products such as: potato products (starch and flakes). Besides permitting better preservation, the drying and processing of root and tubers into dried chips and flour offers other advantages such as: -facilitating transport and increased shelf life -creating new opportunities for the farmer such as new markets and new sources of income. Metal storage bins or water tanks made from smooth or corrugated galvanised metal sheets are used for storing dried products. Dehydration or sun drying is the simplest and lowest cost method of preservation and should be more widely promoted and used in developing countries because it converts a perishable commodity into a stable item with long storage life.

Root and tuber. http://www.ghananewsagency.org/details/Science/Post-harvest-losses-in-root-and-tuber-production-to-be-reversed/?ci=8&ai=45284

4. Strategies of reducing post-harvest food losses in perishable crops (fruits and vegetables)

It is important to highlight that, some varieties of the same crop store better than others. Therefore, to reduce food loss and to achieve maximum shelf-life, only varieties known to store well should be stored.

Stage in the food system	**Description and strategy**
Harvesting	Harvesting should be carried out as carefully as possible to minimize mechanical injury such as scratches, punctures and bruises to the crop. The time of the day when harvesting is done also affects produce quality and shelf-life. In general, harvesting during the coolest time of the day (early morning) is desirable; the produce is not exposed to the heat of the sun and the work efficiency of the harvesters is higher. If harvesting during the hotter part of the day cannot be avoided, the produce should be kept shaded in the field to minimize product weight loss and wilting.
Handling	Mechanical injury provides sites for pest attack and increases physiological losses. Therefore, avoid mechanical injury to the crop while handling. Because of their soft texture, all horticultural products (fruits and vegetables) should be handled gently to minimize bruising and breaking of the skin. The skin of horticultural products is an effective barrier to most of the opportunistic bacteria and fungi that cause rotting of the tissues. Breaking of the skin also stimulates physiological deterioration and dehydration. Reducing the number of times the commodity is handled reduces the extent of mechanical damage.

Sorting and cleaning	Systematic sorting or grading coupled with appropriate packaging and storage, will extend shelf life, maintain wholesomeness, freshness, and quality, and substantially reduce losses and marketing costs. Sorting is done to separate poor produce from good produce, and further classify the good produce based on other quality parameters like size (Bautista and Acedo, 1987).
Packaging	Proper packing is essential to maintain the freshness of leafy vegetable. Packaging should be designed to prevent premature deterioration in product quality, in addition to serving as a handling unit (Bautista and Acedo, 1987). Use clean, smooth and ventilated containers for packaging. This is a very important factor in cutting down losses in these crops during harvesting, transportation, marketing and storage. Use containers that are appropriate for the crop. Examples of packaging containers can be found in Figure F.
Transportation	Minimizing losses during transport necessitates special attention to vehicles, equipment, infrastructure, and handling. Load and unload transport vehicles carefully. Use clean, well-ventilated vehicle covered at the top for transportation. Transport crops during the cool part of the day by driving carefully over smooth roads to minimize damage to crop. Fresh produce must not be watered prior to loading, as this will lead to decay, rotting, and extensive losses. Major causes of losses are improper handling during loading and unloading.
Storage	Only crops with high initial quality can be stored successfully; it is therefore essential to ensure that only crops of the highest quality (mature, undamaged) are stored. Shelf life can be extended by maintaining a commodity at its optimal temperature, relative humidity and environmental conditions.
Processing	Processing is an important value-added activity that stabilizes and diversifies food supplies and creates employment and income opportunities. It can minimize the high perishability problem of leafy vegetables. Processed products are also more stable, have improved digestibility, and permit a better diet diversity, giving consumers access to a wider choice of products and a wider range of vitamins and minerals. Few processing technologies are listed: **Drying, salting, fermenting, and pickling.**

Examples of packaging containers for leafy vegetables

Fig F: Bamboo baskets ACF Bangladesh. (source: Kiaya, V.)

Plastic basket (source: Kiaya, V.)

5. Improve the existing store types

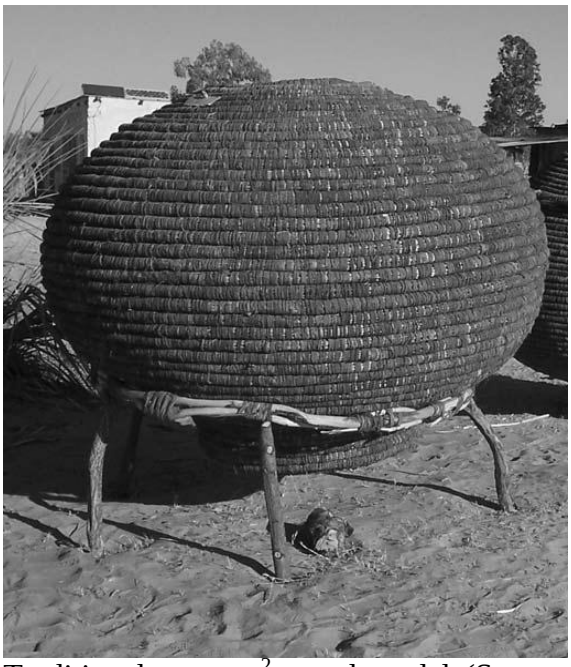
One approach to reducing PHL during storage is either by improving existing store types so that they perform better, or by introducing existing traditional store types (**mud silo**) more effective than those usually used by the communities or by introducing new storage type (**metal silo**).

Mud silo (source: Rick Hoges 2011)

Metal silo (source: spore magazine 2011)

The household metal silo is one of the key post-harvest technologies in the fight against hunger and for food security. It is a simple structure that allows grains to be kept for long periods and prevents attack from pests such as rodents, insects and birds. If the grains have been properly dried (<14 % moisture in the case of cereals and <10 % in the case of pulses and oilseeds) and the household metal silo is kept under cover, there are no problems of moisture condensation inside it.

Plastic granary (Source: Rick Hodges)



Traditional mopane[2] wood model (Source :Rick Hodges)

Traditional granary (Spore magazine, 2011)

5. Impacts of PHL and Food security and livelihoods

Postharvest technologies can contribute to food security in multiple ways. They can reduce PHL, thereby increasing the amount of food available for consumption by farmers and poor rural and urban consumers. For example, the control of the *Larger Grain Borer (LGB)* or *Prostephanus truncanus* greatly reduced the loss of maize in on-farm storage among smallholders in a number of African countries, thus improving their food security (Golleti 2003). The benefits to consumers from reducing losses include lower prices and improved food security. In addition, postharvest activities such as processing and marketing can create

[2] Mopane wood is one of southern Africa's heaviest timbers and is difficult to work because of its hardness.

employment (and thus income) and better food security in the agricultural sector. Therefore, reducing PHL clearly complements other efforts to enhance food security through improved farm-level productivity. Techniques to reduce food losses require cultural and economic adaption. This is so because all food losses occur at a particular socio-cultural environment.
The issue of food losses is of high importance in the efforts to combat hunger, raise income and improve food security in the world's poorest countries (FAO, 2011).

In summary, there is a wide range of technologies available that, if adopted, would enable smallholders and larger producers to improve the quality and quantity of food/grains during postharvest handling and storage.

The PHL strategy should be better integrated into agricultural programmes to provide technical advice and affordable solutions to farmers. For smallholders with few options to invest in improved postharvest practices and technologies, the simplest option and one with only minor financial implications is improvement in basic storage hygiene and good storage management.

References

Atanda, S.A. Pessu P. O., Agoda S., Isong I. U. and Ikotun, 2011. The concepts and problems of post-harvest food losses in perishable crops. African Journal of Food Science Vol. 5 (11) pp.603-6013, 15 October, 2011.

Bautista, O.K.; Acedo, A.L. Jr. 1987. Postharvest handling of fruits and vegetables. Philippines..

Bell, A., Mazaud, F. and Mück, O. 1999. Guidelines for the analysis of postproduction systems. FAO, Rome, Italy. 102p. http://www.fao.org/inpho.

Boxall, R.A. 2001. Post-harvest losses to insects-a world overview. International Bioterioration and Biodegradation, 48(1-4), 137-152. Retrieved from www.scopus.com

Boxall, R.A. 2002. Storage losses. In Crop Post-harvest: Science and Technology Volume 1: principles and Practice (Eds P. Golob, G. Farrell & J.E. Orchard), pp. 143-169. Oxford: Blackwell Sciences, Ltd.

de Lima, C. P. F. 1982. Strengthening the food conservation and crop storage section. Field documents and final technical report, project PFL/SWA/002. Rome: FAO

FAO, 2013. Food wastage footprint: Impacts on natural resources.

FAO, 2011. Global food losses and waste: Extent, Causes and Prevention

FAO , 2004. The State of the Food Insecurity in the World 2004. FAO, Rome.: ftp://ftp.fao.org/docrep/fao/007/y5650e/y5650e00.pdf

FAO, 2002. Postharvest losses: Discovering the full story. Overview of the phenomenon of loses during the postharvest system.

FAO, 1985. Report of Workshop on Production and Marketing Constraints on Roots, Tubers and Plantation in Africa, Vol. 1

FAO, 1983. Food loss prevention in perishable crops
http://www.fao.org/docrep/s8620e/s8620e06.htm

Grolleaud, M. 2002. Post-harvest losses: discoverying the full story. Overview of the phenomenon of losses during the post-harvest system. Rome, Italy: FAO, Agro Industries and Post-Harvest Management Service (AGSI).

Grolleaud, M. 1997. Post-harvest Losses: Discovering the Full Story. Rome: FAO. Available from: http://www.fao.org/docrep/004/ac301e/AC301e04.htm#3.2.1%20Rice

Gross, K., Wang, C.Y. and Saltveit, M.E. 2002. The commercial storage of fruit, vegetables and florist and nursery stocks. USDA Agr. Handb. 66 (http://www.ba.ars.usda.gov/hb66/ index.html)

Hodges, R.J., ,.Buzby, J.C, Bennett, B.. 2011. Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. Journal of Agricultural Science, 2011 (149), 37-45, . © Cambridge University Press 2010.

Kader, A.A. 2002. Postharvest technology of horticultural crops. 3rd ed. Univ. Calif. Agr. Nat. Resources, Oakland, Publ. 3311.

Kitinoja, L. and Gorny, J.R. 1999. Postharvest technology for small-scale produce marketers: economic opportunities, quality and food safety. Univ. Calif. Postharvest Hort. Series No. 21.

Knight, A. and Davis, C., 2007. What a waste! Surplus fresh foods research project, S.C.R.A.T.C.H. http://www.veoliatrust.org/docs/Surplus_Food_Research.pdf

Knoth, J. 1993. Le stockage traditionnel de l'igname et du manioc et son amélioration. Hambourg, GTZ-Post-harvest Project, 95 p.

Lundqvist, J., C. de Fraiture and D. Molden. Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain. SIWI Policy Brief. SIWI, 2008
http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_fork_2008.pdf

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B.,. Svihus, B., Prins, A. G., Kaltenborn, B. P. (Eds).. The environmental food crisis-The environment's role in averting future food crisis.: UNEP, Nairobi

Parfitt, J., Barthel, M.and Macnaughton, S. 2010. Food waste within food supply chains: quantification and potential for change to 2050

SPORE, 2011. Post-harvest management. Adding value to crops. The magazine for agricultural and rural development in ACP countries.N° 152. http://spore.cta.int

Stuart, T. 2009. Waste uncovering the global food scandal. Penguin Books: London, ISBN: 978-0-141-03634-2

The World Bank, NRI and FAO, 2011. Missing Food: The case of postharvest grain Losses in Sub-saharan Africa. Report No. 60371-AFR

Voices Newsletter. 2006. Increasing post-harvest success for smallholder farmers. No: 79: http://www.farmradio.org/english/partners/voices/Voices_79.pdf

WRAP, 2008. Food waste report 2: The food we waste. WRAP, U.K. http://www.wrap.org.uk/downloads/The_Food_We_Waste_v2__2_.d3471041.5635.pdf