Measuring postharvest losses of fresh fruits and vegetables in developing countries

PEF White Paper 15-02

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Introduction

Finding detailed information on the methods used to measure postharvest losses for fruit and vegetable crops can be a difficult task and, over the past few decades, researchers have developed many different methods, each focusing on different aspects of the value chain and on varying types of food losses. The objective of this white paper is to gather existing information and compile the findings into a single document that can be easily shared and used as a basis for future research and method development. Literature searches on measurements of postharvest losses of fruits and vegetables were conducted using a wide range of databases and journals, and for both published and unpublished sources over a 25-year period (1990-2015). The findings are described for key studies and the overall results of the literature review are organized by region/country, types of crops, measurement methods (surveys/interviews or sampling/quantitative measurement) and the key parameters being measured along horticultural value chains. Summary tables of the findings on percentages of measured losses are presented for many different crops, in terms of physical losses, qualitative losses, and/or decreases in economic value.

Literature searches and reviews

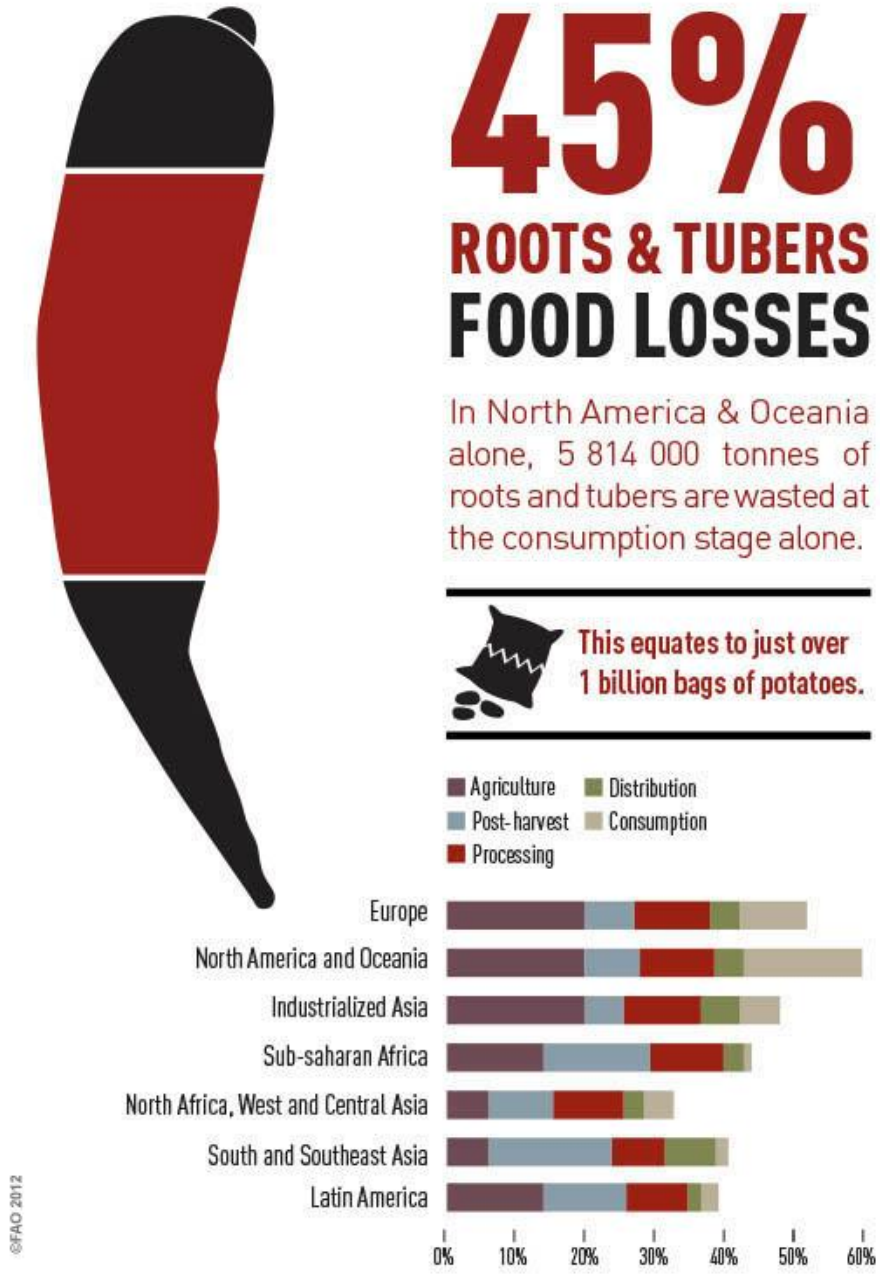
Literature searches on fruit and vegetable postharvest losses were conducted in a wide range of databases, journals, and other sources (both published and unpublished), using parameters that included a long list of postharvest horticulture related key words and a 25 year time period (1990-2015). Online databases included AidData, USAID Documents, World Bank Projects and Operations, UN FAO, INPhO, and DEVEX.

The authors were assisted in the initial literature review conducted during 2009-10 for a World Food Logistics Organization (WFLO) research project by a team of eight scientists and educators from the USA, Europe, Middle East/North Africa, India and Chile. As a team we had the language skills to read and review the existing literature in English, French, Spanish, Arabic and Hindi. We reviewed the global literature up to and including 2010 to learn about any postharvest loss measurement activities undertaken in the field as part of projects funded by the World Bank, US Agency for International Development (USAID), US Department of Agriculture (USDA), Consultative Group on International Agricultural Research (CGIAR), UN Food and Agriculture Organization (FAO), Japanese International Cooperation Agency (JICA) and the various European Union development entities. JICA, for example, has done quite a bit of horticultural development work in India, Kenya, the Middle East and Indonesia. The literature review and keyword searches were updated in 2012 by Dr. Adel A. Kader and again during mid-2015 by Dr. Lisa Kitinoja, and this white paper includes pertinent results covering the entire period spanning 1990-2015. We did not include studies undertaken in the laboratory to compare the effects of different postharvest technologies on losses of fresh produce, and we did not include food processing studies.

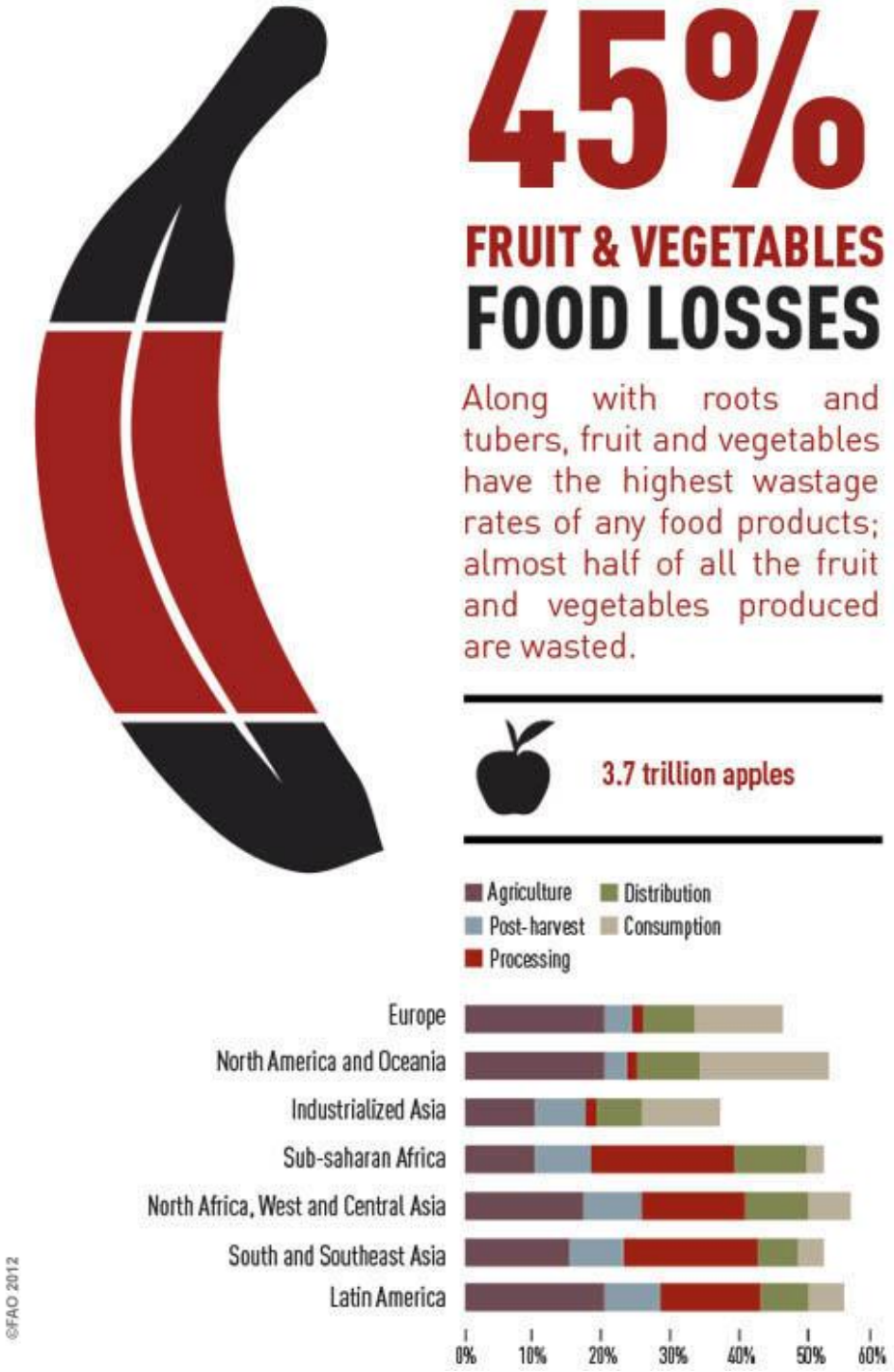
A few international studies were conducted in the 1970s and 1980s (Ceponis and Butterfield, 1973; National Academy of Sciences, 1978; Cappellini and Ceponis, 1984; Blond, 1984), and a few postharvest systems assessments were done for vegetables in the USA in the 1980s (Brennan and Shewfelt, 1989; Prussia et al., 1986), but a long gap was found in the 1990s through the early 2000s. Most of the investigations of which we are aware were done by private consultants as quick assessments during the start of postharvest infrastructure development projects and the results are still considered proprietary information. More recently, a wave of synthesis studies (compiling existing information

from different studies) and meta-analyses (reanalyzing existing data) have been done to characterize food losses by INTERPACK (Gustavsson et al., 2011), the World Resources Institute (Lipinski et al., 2013), a United Nations High Level Panel of Experts (HLPE 2014) and International Research Development Center (IDRC) by scientists affiliated with the International Centre of Insect Physiology and Ecology (known as ICIPE) (Affognon et al., 2015). The resulting estimates of postharvest losses for horticultural crops from these widely dispersed studies vary somewhat, and differ by region, country, crop and season, often without much explanation of what is being measured, when, or how. Nevertheless, the UN FAO SAVE FOOD Initiative currently uses the figures of 45% for losses of both roots/tuber crops and fruits/vegetables, and many international development authorities (e.g. the UNFAO, the World Bank and USAID) and journal article authors citing primary works typically quote a general range of 30 to 50% postharvest losses.

The diagrams and infographic shown on the following pages are based upon synthesis studies and developed for global dissemination by the UN FAO SAVE FOOD Initiative (FAO, 2012).



Source: UN FAO SAVE FOOD Initiative 2012



Source: UN FAO SAVE FOOD Initiative 2012

Postharvest losses of fruits and vegetable crops

Data on postharvest losses generally have been collected either via surveys/interviews or via sampling/direct measurements, and are reported as physical and/or economic loss. Occasionally data are provided on qualitative losses (due to damage, disease, pests, appearance changes, etc.).

Written surveys and interviews require people to try to recall or remember what happened in the past, sometimes weeks, months or even a season earlier than when the data are being collected, and so are generally considered to be less accurate than making direct measurements. Sampling or direct measurements are considered to be more accurate, but may not be highly reliable. Often when measurements have been made in the field, little or no information is provided regarding important variables such as how much time has passed since harvest, the temperature of the produce and ambient air, relative humidity or the type of packaging. The time of harvest, for example, could be hours, days or weeks before the sampling is done, but the exact time of the harvest is generally unknown to the data collector, while both qualitative and quantitative losses continue to occur in the period following harvest.

For this literature review, the focus was on assessing written articles and project reports on postharvest losses in developing countries, and on gathering as many examples of direct measurements (i.e.: sampling of changes in weight, quality ratings or market value) as possible. Many of the published reports include general estimates of postharvest losses by the author(s) and/or refer to loss estimates or measurements published by other authors. We found 63 unique documents (51 published articles and 12 project reports) that **included primary data** on postharvest losses of fruits and vegetables, including 18 from Sub-Saharan Africa, 6 from North Africa/Middle East, 32 from Asia & the Pacific, and 7 from Latin America/Caribbean. Many of these reports covered multiple crops and/or multiple countries, and provide data based on interviews or sampling as follows:

Table 1. Postharvest losses literature review

Published Reports	**Sub-Saharan Africa**	**North Africa/ Middle East**	**Asia & the Pacific**	**Latin America & the Caribbean**	**Total**
Survey/Interviews	6	3	16	4	29
Sampling/Measurements	12	3	16	3	34

It is important to remember that surveys and interviews do not always result in gathering accurate information on postharvest losses. As an historical example and warning, sampling the physical losses of potatoes, grapes and tomatoes at Egyptian farms, wholesale and retail markets was reported to total 17.6, 28.0 and 43.2% respectively, yet interviews of these same value chain players resulted in reported average total losses of 8.8, 11.9 and 27.6%, indicating that their perceptions of losses were much lower than was the reality (Blond, 1984). In addition, losses over the links of a horticultural value chain are cumulative, but the assessments are not always carried out along the entire chain or reported in detail for the entire chain. Finally, the researcher's choices regarding how to report data can lead to confusion. For example, someone reporting 10% losses during harvest and another person reporting 10% losses during marketing can sometimes be reported as an average of 10% losses for that commodity, but in another case be reported as 20% losses (the sum of the two measurements made for that commodity) and

occasionally will be reported as a cumulative amount (10% plus 10% of the remaining 90% = 19% losses). Table 2 provides an example of how different ways of estimating postharvest losses can result in different reported data.

Table 2: Three different ways to estimate the total postharvest loss % of a food crop:

Step of the postharvest chain	Stakeholder / value chain actor estimates	Surveys (recall)	Measurements (sampling)
Harvest	2%	2%	2% of the initial 100%
Postharvest handling	3%	3%	3% of remaining 98%
Transport	5%	5%	5% of 95%
Storage	10%	10%	10% of 90%
Marketing	2%	2%	2% of 81%
			79.4% remaining
Reported as:	range of 2% to 10% losses	Total loss of 22%	Cumulative losses of 20.6%

For illustrative purposes only.

As shown in Table 3, postharvest losses for a single commodity, in this case mangoes, can vary by country, by season, and by the data collection method. Pre-harvest factors, such as insect infestation and rainfall, can have a major impact on postharvest losses.

Table 3. Postharvest losses in mangoes

Country	**Method used**	**Losses (%)**	**Reference**
Benin	Sampling	17 (early April) 70 (mid-June) due to fruit flies	Vayssieres et al 2008
Brazil	Survey	28	Choudhury & da Costa 2004
Costa Rica	Sampling at wholesale market	14.1 (dry season) 84.4 (rainy season) - due to Anthracnose	Arauz et al 1994
Mexico	Interviewing consumers	< 10 at home	Baez-Sanudo et al 1994
Pakistan	Survey Sampling	31 36.1	Mushtaq et al 2005 Malik & Mazhar 2008

Since physical damage is a leading cause of postharvest losses, the extent of losses often depends on the relative susceptibility of the commodity to physical damage. As shown in Table 4, losses in tomatoes ranged from 18 to 28% while losses in onion, potato, and yam ranged from 9 to 12.4%. Tomatoes harvested red ripe (in Ghana) experienced much higher postharvest losses than tomatoes harvested at the breaker or turning stage of maturity (in Rwanda) when measured using the same sampling loss assessment methods on the farm (F), at wholesale (WS) and retail (R) markets (WFLO 2010).

Greater postharvest losses of bananas (increased physical damage incidence and severity) were associated with longer transport distance on poor roads (George & Mwangangi, 1994). Lower losses in general were reported in Fiji and in Laos, where the vegetable supply chain is rather short and direct (Underhill & Kumar, 2014; Weinberger et al 2008). In contrast, "there is higher retailer participation in Cambodia and Vietnam, i.e. supermarkets, wet market vendors, grocery stores and street vendors, and this is associated with higher losses" (Weinberger et al 2008).

Table 4 summarizes some of the data that have been collected for various fruits and vegetables in Sub-Saharan Africa, Asia/Pacific and North Africa/Middle East.

The number of people surveyed or the number of samples taken as the basis for reporting average % losses varies for each study, as do the total number of data points collected. For example, Weinberger et al (2008) surveyed groups of 50 people handling 2 to 5 crops in each of three countries, and Olayemi et al (2010) surveyed a random sample of 110 farmers in Nigeria (60 tomato growers, 25 bell pepper growers and 25 hot pepper growers). WFLO (2010) measured assorted postharvest loss variables for 3 samples on each of 10 farms, 10 wholesale market places and 10 retail market stalls for each crop studied.

Table 4. Postharvest losses of fruits and vegetables in selected developing countries

Region and Country	**Commodity**	**Method used**	**Losses**	**Reference**
Sub-Saharan Africa				
Benin	Tomato	Sampling	28% in volume; 40% in economic value in 5 days	IITA 2008
Ghana	Tomato	Interviews	20%	Bani et al 2006
Ghana	Tomato	Sampling	25% (F); 21.5% (WS); 23% (R) physical losses	WFLO 2010
Ghana	Yams	Sampling	25-63% price discount depending on degree of quality losses	Bancroft et al 1998
Kenya	Banana (imported from Uganda)	Sampling	18.2 – 45.8%	George & Mwangangi 1994
Kenya	Dessert Banana Plantains	Survey & Sampling	11.2% physical losses; 30-50% reduced market value 4.6% physical losses; 20-30% reduced market value	Save Food 2014

Region and Country	Commodity	Method used	Losses	Reference
Niger	Dried onions and tomatoes	Sampling	15% discarded; 65% sold with high levels of quality losses	Tröger et al 2007
Nigeria	Tomato Bell pepper Hot pepper	Survey	20% (farm); 28% (transit) 12% (farm); 15% (transit) 8% (farm); 10% (transit)	Olayemi et al 2010
Nigeria	Yam	Survey	12.4% (economic loss = 10.5%)	Okoh 1997
Rwanda	Tomato	Sampling	7.8% (F); 10.7% (WS); 14.7% (R) physical losses	WFLO 2010
Tanzania	Sweetpotato	Sampling	32.5-35.8%	Rees et al 2001
Asia				
Cambodia Laos Vietnam	Tomato	Survey	24.6% 16.9% 19.1%	Weinberger et al 2008
Cambodia Laos	Yard-long bean	Survey	21.8% 12.2%	Weinberger et al 2008
Laos Vietnam	Chili pepper	Survey	10.7% 16.9%	Weinberger et al 2008
Fiji	Vegetables Fruits	Sampling	0.07 to 2.44% 4.07 to 10% in municipal markets	Underhill& Kumar 2014
Bangladesh	Fruits & Vegetables	Survey	23.6-43.5%	Kamrul Hassan et al 2010
Bangladesh	Litchi	Survey	8% at harvest 4.6% during handling 7.5% by consumer	Molla et al 2010
Pakistan	Tomato Tomato, potato, onion	Survey	20% 22, 12, 9%	Mujib et al 2007 Zulfiqar et al 2005

Region and Country	Commodity	Method used	Losses	Reference
Sri Lanka	Bananas	Survey	20% from farm gate to retailer	Wasala et al 2014
Sri Lanka	Tomato	Survey	54% cumulative (measured at wholesale market)	Rupasinge et al 1991
North Africa/Middle East				
Egypt	Oranges Tomatoes	Sampling	14% 15%	El Shazly et al 2009
Egypt	Pomegranate Onion	Sampling	23% 19%	Tolba et.al 2009
Iran	Grapes	Survey	13%	Jowkar 2005
Jordan	Tomato, eggplant, pepper, squash	Sampling	18, 19.4, 23, 21.9%	El-Assi 2002
Oman	Fresh produce	Survey	3 – 19%	Opara 2003
Saudi Arabia	tomato cucumber figs grapes dates	Survey	17% 21.3% 19.8% 15.9 % to 22.8% 15%	Al-Kahtani and Kaleefah 2011

The WFLO (2010) Appropriate Postharvest Technologies Planning Project, undertaken for the Bill & Melinda Gates Foundation, measured postharvest physical and quality losses for a variety of key fruits and vegetables in four countries, and provided detailed measurements of % physical losses, % mechanical damage and % decay losses at the farm, wholesale and retail levels. In each case, the % losses are not added across the 3 locations, but reported separately for each type of damage at each location (see Table 5). Quality losses due to mechanical damage were consistently very high in Sub-Saharan Africa, regardless of the country or crop.

Postharvest Tool Kit

Example of a tool kit used for measuring postharvest losses in fruits and vegetables (WFLO 2010)

Table 5: Postharvest losses of fruits and vegetables in Ghana, Benin, Rwanda and India at the farm (F), wholesale market (WS) and retail market (R).

Country	Commodity	Method used	Physical Losses (% sorted out and discarded)	Quality Losses (% mechanical damage)	Quality Losses (% decay)
Ghana	Tomatoes	Sampling	25.1 (F), 21.5 (WS), 23 (R)	33.5(F),21.5(WS),10.5(R)	17 (F), 14 (WS),11.5 (R)
Ghana	Cabbage	Sampling	20.1 (F), 6.5 (WS), 28.1(R)	54 (F), 32 (WS), 45 (R)	13 (F), 8 (WS), 5 (R)
Ghana	Eggplant	Sampling	13.9 (F),11.3(WS),16.2 (R)	22 (F), 19 (WS), 9.5 (R)	2.8 (F), 2 (WS), 0 (R)
Ghana	Mangoes	Sampling	6 (F), 10.4 (WS)	2.3 (F), 5 (WS), 8 (R)	2.5 (F), 0.4 (WS), 1 (R)
Ghana	Okra	Sampling	16.6 (F), 2.3 (WS), 6.3 (R)	28 (F), 4.5 (WS), 15 (R)	6 (F), 0 (WS), 8.5 (R)
Benin	Tomatoes	Sampling	23 (F), 31.2 (WS), 26.4 (R)	29 (F), 27.5(WS), 31.2(R)	24 (F),21.2(WS),27.5(R)
Benin	Peppers	Sampling	5.9 (F), 6.2 (WS), 11 (R)	15 (F), 7 (WS), 10 (R)	24 (F), 18 (WS), 8 (R)
Benin	Amaranths	Sampling	17.3 (F), 17.3 (R)	34.5 (F), 89.5(WS), 79(R)	47 (F)
Benin	Oranges	Sampling	10 (F), 11.6 (WS), 10.9 (R)	15 (F), 41 (WS), 51 (R)	5 (F), 16.4 (WS), 33 (R)
Rwanda	Tomatoes	Sampling	7.8 (F),10.7 (WS), 14.7(R)	2 (F), 11 (WS), 12.5 (R)	6 (F), 7 (WS), 6.5 (R)
Rwanda	Amaranths	Sampling	8.3 (F), 2 (WS), 25 (R)	18.5 (F),15 (WS), 32.5(R)	7.5(F),12.5(WS),13.5(R)
Rwanda	Bananas	Sampling	14.8 (F),35.1(WS),30.1 (R)	7.5 (F), 19 (WS), 25 (R)	0 (F), 9.5 (WS), 0 (R)
Rwanda	Pineapples	Sampling	10.4 (F), 17 (WS), 15.9 (R)	11.8 (F), 20 (WS), 21 (R)	0 (F), 2.9 (WS), 2 (R)
India	Tomatoes	Sampling	8.7 (F), 15.1 (WS), 16.4(R)	10.5 (F), 7.5 (WS),16 (R)	5 (F), 7 (WS), 8.5 (R)
India	Cucurbits	Sampling	12.7 (F), 3.8 (WS), 9.2 (R)	9 (F), 6 (WS), 5 (R)	4.5 (F), 7(WS), 5 (R)
India	Okra	Sampling	18.5 (F), 7.9 (WS), 10 (R)	8.8 (F), 3.8 (WS), 6 (R)	2.6 (F), 2 (WS), 8.8 (R)
India	Mangoes	Sampling	6.5 (F), 7.9 (WS), 7.1 (R)	6.5 (F), 6 (WS), 9.5 (R)	5 (F), 7 (WS), 7.5 (R)
India	Litchis	Sampling	9.8 (F), 11.4 (WS), 10.1(R)	14 (F), 6 (WS), 10 (R)	8.5 (F), 8 (WS), 8.7 (R)

Source: Illustration from WFLO 2010 Slide Deck (Kitinoja & Cantwell 2010)

Sampling based studies in Tanzania reported that up to 86% of sweet potatoes were damaged during postharvest handling and transport to local market, resulting within a few days in a 9% loss of market value (Tomlins et al 2000; Ndunguru et al, 2000). The reason market value did not decline further is that consumers in Tanzania tolerate slight to moderate skinning injury and other symptoms of root damage in sweet potato. In a follow-up study undertaken by Tomlins et al (2007), the range of losses was 23.7 to 66.9%.

Table 6. Percentage of sweet potato roots with severe damage in Tanzania

	Sampling Location			
Type of damage	Farm	**Lakeshore**	**Port**	**Market**
Broken roots	1	4	18	18
Skinning injury	1	7	43	53
Cuts	2	2	5	4

Source: Tomlins et al 2000; Ndunguru et al, 2000.

Ohiokpehai et al (2009) reported for Tanzania that a survey of wholesalers and retailers at the Kariakoo Central Market showed a wide range from low to high incidence of postharvest losses in quantity (physical wastage) and quality downgrading affecting all major types of produce. The reported magnitude of physical losses ranged between 0-33% for fruits and 0.4-35% for vegetables, while quality loss affected 0.5-60% of the total quantity of vegetables and 5-80% of the fruits being traded. A high incidence of postharvest losses was reported by supermarkets and street vendors. One supermarket (Shoppers' Plaza) reported the magnitude of fresh produce losses ranging from 16% (onion), 20% (banana), 30% (mango), 30-40% (orange), and 50% (tomato). "These losses were attributed mainly to inadequate cool chain management." (p.9).

Interviews conducted in Ethiopia reported a very wide range of estimates of postharvest losses as shown in Table 7 (Tadesse, 1991). In general, the more delicate and highly perishable types of produce (guava, tomatoes) suffered higher losses than the less perishable commodities (citrus fruits, carrots, cabbage).

Table 7. Estimated postharvest losses of fruits & vegetables in Ethiopia based on interviews

Fruits	**Losses (%)**	**Vegetables**	**Losses (%)**
Guava	49.2	Tomato	19.4
Pineapple	28.2	Melon	16.7
Mango	26.3	Onion	10.7
Mandarin	17.4	Potato	6.0
Papaya	11.5	Sweet potato	2.9
Orange	9.0	Beet root	2.7

Fruits	Losses (%)	Vegetables	Losses (%)
Banana	8.1	Green beans	2.2
Grape	4.3	Sweet pepper	2.0
Grapefruit	1.9	Carrot	1.1
Lemon	1.3	Cabbage	1.1

Source: Tadesse, 1991.

Many of the studies and reports we analyzed for this white paper come from India. In recent years, the Government of India (GOI) has begun to look more seriously at postharvest wastage and has been funding research on how to reduce losses on the farms and in the marketplaces. The most important vegetables are listed first in Table 8, having been investigated in 1993 by S.K Roy and his team at the Indian Agricultural Research Institute (IARI). Vegetables such as potatoes, onions and tomatoes have been the most heavily studied, followed by a few fruit crops.

Table 8. Postharvest losses reported for fruits and vegetable crops in India

Commodity	Method used	Losses (%) in India	Reference
Vegetables			
Potato	Sampling Interviews Sampling Sampling Sampling	18 19.8 12.8 (field) +12.4 (wholesale) + 9.5 (retail) 29.4 (economic loss = 16.2) 10.5	Roy 1993 Gauraha 1999 Pandey et al 2003 Kumar et al 2004 Kumar et al 2006
Onion	Sampling Sampling Sampling	30 12.9 15.7	Roy 1993 Kumar et al 2006 Chaugule et al 2004
Tomato	Sampling Sampling Sampling Interviews Interviews Interviews Sampling	13 30.3 – 39.6 11.9 – 21.4 20 32.6 35 1% economic loss	Roy 1993 Pal et al 2002 Sharma et al 2005 Ajay et al 2003&2004 Gauraha 1999 Gajbhiye et al 2008 WFLO 2010
Cauliflower	Interviews Sampling Sampling Interviews	22.4 28.6 – 35.1 12.9 15 – 20	Gauraha 1999 Pal et al 2002 Wadhwani & Brogal 2003 Gajbhiye et al 2008

Commodity	Method used	Losses (%) in India	Reference
Cabbage	Sampling Sampling Interviews	24.9 – 30.4 9.4 15 – 20	Pal et al 2002 Wadhwanj & Brogal 2003 Gajbhiye et al 2008
Cucurbits	Sampling	52% economic loss	WFLO 2010
Bell pepper	Sampling	6.7 – 17.1	Sharma et al 2005
Fruits			
Citrus	Sampling	27	Roy 1993
Mango	Sampling Sampling	26 20% economic loss	Roy 1993 WFLO 2010
Okra	Sampling	31% economic loss	WFLO 2010
Guava	Sampling	20	Roy 1993
Litchis	Sampling	30% economic loss	WFLO 2010
Mango Grapes Banana Pomegranate	Sampling	29.7 (local market) 14.4 (local); 21.3 (distant market) 28.8 (wholesale); 18.3% (cooperative) 35.4 (distant market)	Sreenivasa Murthy et al 2009


LK interviewing farmers in India (2009)

Postharvest loss % for fruits as reported by Sreenivasa et al (2009) depend upon the specific marketing channel being assessed, which includes variables such as the amount of time it takes to market the crop (delays in marketing) as well as the distance to market (damage during transport). The following diagram is provided to illustrate how marketing channels may differ for each crop and country.

Marketing channels for bananas in Karnataka, India (Sreenivasa et al (2009):

Channel-1 : Farmers ⟶ Wholesalers ⟶ Retailers ⟶ Consumers

Channel-2 : Farmers ⟶ Farmers Co-operative Society ⟶ Consumers
(Wholesale and Retail)

Channel-3 : Farmers → Pre-harvest contractors → Wholesalers → Retailers → Consumers

Channel-4 : Farmers ⟶ Wholesalers ⟶ Consumers

Reported losses in Nepal for a few vegetable crops appear to be related to how long the crops are handled and stored before marketing (Udas et al, 2005). Tomatoes and fresh radishes are highly perishable and therefore are sold as rapidly as is possible, while cabbage and cauliflower can be kept much longer and are often transported to distant markets before sale.

Table 9. Postharvest losses of vegetables in Nepal (reports based on sampling)

Vegetable	**Farm (% loss)**	**Retail (% loss)**	**Total (% loss)**
Cauliflower	6	41	47
Cabbage	9	34	43
Radish	6	4.5	10.5
Tomato	3	7	10

Source: Udas et al, 2005

Information gaps and missing data

We have identified concerns in terms of the quality of available information, since many of the data were collected via surveys or interviews, and we have found many information gaps, since there are regions, countries and key crops with missing data. Underhill & Kumar (2014) reported, "There have been no previous studies that have sought to quantify postharvest horticultural losses in Fiji, or the wider South Pacific region". Researchers rarely made comprehensive measurements along the entire value chain, or reported on all three aspects of loss: i.e. physical, quality and economic losses. The numbers of interviews or samples used to determine and report on % loss averages were inconsistent and widely variable. Reports of % losses for a specific crop can vary over time (see data reported for tomatoes, cauliflower or cabbage in India in Table 7). Percent losses are occasionally reported as averages of several or many crops (see Carvalho et al 2003, and Fehr & Romao, 2001 in Table 9; Underhill & Kumar, 2014), or as averages for a specific crop across several countries (Weinberger et al 2008).

One of our findings is that the levels of reported losses worldwide for fruits and vegetables do not appear to have changed much between the 1970s (when the 30 to 40% losses estimate was first published by the National Academy of Sciences) and the present time. The range of reported losses for various crops is enormous (from 0 to 80%) and this wide range is most likely due to the nature of the produce (whether it is highly perishable, moderately perishable or less perishable) plus a host of unreported contributing factors (such as initial disease incidence in the field, time from harvest, temperature during handling, weather conditions, type of packages used, etc.). When standard deviations are reported, they tend to be very high. For example, Weinberger et al (2008) reported that farmers (N=187) experienced average losses of 6.4±5.7% in Cambodia, Laos and Vietnam; George & Mwangangi (1994) reported that 10±9.88% transit losses in bananas (N=15) being transported from Uganda to Kenya; and Kitinoja & Al Hassan (2012) reported that the % mechanical damage for individual samples of cabbage handled in very large sacks in Ghana (N=30) was measured at 55±20.1% (farm), 32±25.7% (wholesale), and 45±27.6% (retail market).

The main factors that are most consistently related to higher levels of postharvest losses include rough handling, use of poor quality packages, high postharvest handling temperatures and delays in marketing (Kitinoja & Al Hassan 2012; WFLO 2010; Kitinoja and Cantwell 2010; Molla et al 2010). Losses for highly perishable leafy green vegetables have been measured to be as high as 70 to 80% in West Africa, and for losses in fruits to be 50 to 70%, especially during the rainy season. It is not unusual to find postharvest losses reported to average 20 to 50% during the period of time between harvesting and final retail marketing, matching the figures used for UN FAO SAVE FOOD promotional info-graphics and posters. This amounts to an enormous waste of seeds and planting materials, land, energy, fertilizers, water, labor and other productive resources.

Reported losses for fruits and vegetables in the least developed countries, while high, are not much different from the levels of losses reported for countries that are considered more developed. For comparison purposes, the following tables summarize some of the reported postharvest losses for horticultural crops in Latin America, China and Thailand.

Table 10. Postharvest losses of fruits and vegetables in Latin America

Country & Commodity	**Method used**	**Losses (%)**	**Reference**
Brazil: Tomato Bell pepper Carrot	Interviews	30 30 12	Vilela et al 2003
Brazil: Pineapple, banana, orange, papaya & passion fruit	Sampling	Wholesale = 11.6 Retail = 7.7 Total = 19.3	Carvalho et al 2003
Brazil: Fruits & Vegetables	Interviews	16.6 (marketing chain) + 3.4 (home consumer)	Fehr & Romao 2001
Uruguay: Onion	Sampling	21.7	Zaccari et al 1995

Table 11. Postharvest losses of vegetables in China

Commodity	Method used	Losses (%)	Reference
Chinese cabbage Broccoli Bunching onion	Interviews	10 – 15 10 – 15 10 - 12	Zheng et al 2001
Pak Choi Chinese cabbage	Sampling	27.2 - 34.5 22.7 - 61.6	Wang & Bagshaw 2001
Fruits & vegetables	Interviews	15 - 35	Feng 2001

Table 12. Postharvest losses of vegetables in Northern Thailand based on sampling at the collection center

	Range of Losses (%)		
Vegetable	**due to: Bruises**	**due to: Pests & Disorders**	**Total % Losses**
Head lettuce	21.3 – 27.4	20.7 – 40.1	48 - 61
Leaf lettuce	23.3 – 30.0	19.5 – 35.9	50 - 60
Spinach	17.5 – 24.8	17.6 – 30.0	35 – 52
Cabbage	13.8 – 19.2	10.9 -18.5	28 – 32
Celery	21.9 – 24.5	17.5 – 35.9	42 - 58

Source: Boonyakiat, 1999

Conclusions and Recommendations

Our literature reviews have uncovered a range of information on postharvest losses, but identified many more information gaps, in terms of regions, countries, crops and loss characteristics (whether quantitative, qualitative or economic). While we recommend that any missing data be collected by scientists and graduate students working in the field of postharvest technology, and that existing loss data be updated, the assessment methods utilized for data collection and data analyses must be better standardized so that the baseline results can be interpreted, compared to future measurements and therefore be more useful for supporting local, national and regional efforts to reduce postharvest losses.

The basis for loss measurement can be monetary loss or unit loss (Bell et al, 1999; LaGra 1990; Kantor et al, 1997). Monetary loss depends upon market prices, and unit loss can be measured as changes in numbers of items or as weight loss percentages.

One advantage of **monetary loss measurement** is the characterization of the accumulated costs of a commodity. Losses expressed in monetary terms should increase at each and every step in the postharvest handling chain, up until the commodity is consumed. It is reasonable to assume that the economic value of a commodity, as represented by price per kg, would probably be a true measure of costs as averaged over a period of years. Prices at any one time and place, however, will vary with supply and demand, various governmental support programs, and other market factors. Monetary losses are one of the key factors that can lead people to seek advice and make investments in postharvest technologies that can help to reduce losses.

Unit loss measurements characterize losses of a commodity expressed by the percentage of units or a percentage loss of weight. Often loss is counted after the unit is considered unfit for human consumption, and is being discarded. Some problems with unit loss measurements include the following:

1) The point at which a commodity becomes inedible often depends upon the social-economic level of the consumers and/or on local cultural preferences.
2) Reduction of quality, condition, or appearance might involve serious monetary losses but would not be reflected in the data as long as the produce was consumed.
3) Diversion of produce to a secondary or salvage market might represent a real loss in monetary terms, but would not be considered a loss by this method because it would be consumed.
4) Moisture loss is an important factor in quality and consumer acceptability of fresh fruits and vegetables. Such loss of acceptability would be measured as a unit loss only if dehydration was so severe as to render the commodity unfit for human consumption.

There is simply no "easy" way to measure postharvest food losses. Since fruits and vegetables are handled by many people, sometimes over a long period of time, produce samples may be examined for loss at convenient points in the distribution chain. Many past measurements have targeted postharvest losses occurring on the farm (at harvest), in the packinghouse, after storage, and at wholesale and retail markets. Differences in pack-out commodity weight and the weight upon entering the packinghouse is the loss due to cullage. Likely included as culls are small sizes, immature and over-mature or over-ripe produce, and variously damaged or defective (deformed, hail or frost damaged, etc.) units. Culls are a postharvest loss unless there was an available alternate use or secondary market. For example, if culled fruits were processed to jams or candies, further measurements would be required to determine the extent to which losses in the processed products occurred. If long-term storage is involved in the value chain, postharvest loss sampling may occur as packed produce is removed from cold or dry storage to be loaded into transit vehicles. Measurements of weight are commonly made before and after transportation, so weight loss can usually be determined in distribution centers or upon arrival at retail stores.

The UN FAO SAVE FOOD Initiative is developing a methodology for measuring postharvest losses that includes **screening** (literature reviews and key informant interviews), **surveys** (estimates and observations), **sampling** (measurements) and **synthesis**. This methodology is known as the 4 S

Approach, and combines many of the types of data collection methods that were used for the postharvest loss assessments we have reviewed for this white paper. The initial case study for the 4 S Approach was on postharvest losses in fish (Diei-Ouadi and Magwe, 2011), but case studies on horticultural crops have been completed in Kenya (SAVE FOOD 2014) and are currently underway in Cameroon, Rwanda, Uganda, India and Indonesia. The results are being synthesized and a series of reports on critical loss points and potential solutions will soon be published by the UN FAO. In October 2015, ADMI will host the 1st International Congress on Postharvest Loss Prevention in Rome, which will include a professional session on measuring postharvest losses. In addition, the World Resources Institute is developing a global reporting protocol that will allow countries to standardize data on food losses and share results on a more regular basis.
(http://www.wri.org/sites/default/files/uploads/2014_FLW_Protocol_Overview_Dec.pdf).

When these loss assessment methodologies and protocols have been more fully developed, The Postharvest Education Foundation will provide further guidance via a follow-up white paper on recommended postharvest loss assessment and reporting methods.

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