Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.5, 2015

Extent, Causes and Reduction Strategies of Postharvest Losses of Fresh Fruits and Vegetables – A Review

Gebru Hailu (Corresponding author)
School of Agriculture, Wolaita Sodo University, P.O. Box 138, Ethiopia
E-mail: hailugebru13@yahoo.com

Belew Derbew
College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Ethiopia
E-mail: dbelew@yahoo.com

Abstract
Proper postharvest handling of food produces is more important than the intensive and extensive farming in securing food for a nation, because losses are not only a waste of food but also they represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce recourses such as water. Postharvest losses of horticultural crops in general and fresh fruits and vegetables (perishables) in particular are very common problems in developing countries, like Ethiopia, which has a negative impact on the food security program. This is partly because of their perishable nature, lack of knowledge and shortage of capital. The other reason is that most of these perishables are produced by small-scale farmers those who have limited knowledge and financially poor in the developing countries. Therefore, estimation of postharvest losses of fresh fruits and vegetables is highly important for awareness creation to manage the produce properly so as to save from spoilage and damages by physical and physiological means. The objectives of this review are, therefore, to assess the available literatures on the postharvest losses of fresh fruits and vegetables in an attempt to identify priority areas of the problem; to identify the causes of losses of perishables in order to avoid the causes for the reduction of losses; and to identify the possible strategies that can reduce losses and maintain quality of the commodities during the period.
Keywords: Fresh fruits and vegetables, perishables, postharvest loss

1. Introduction

Fruits and vegetables provide different benefits and play a significant role in human nutrition, especially as sources of vitamins, minerals, and dietary fiber (Wargovich, 2000). Fruits and vegetables in the daily diet have been strongly associated with reduced risk for some forms of cancer, heart disease, stroke, and other chronic diseases (Wargovich, 2000; Tomas-Barberan and Espin, 2001). Some components (phytochemicals) of fruits and vegetables are strong antioxidants and function to modify the metabolic activation and detoxification of carcinogens, or even influence processes that alter the course of the tumor cell (Wargovich, 2000).

High value products of horticultural crops also provide an opportunity for less developed countries, like Ethiopia, to compete for a share of profitable export market (Lambaste, 2005). Particularly, diversification of traditional agricultural commodities into high value horticultural production and exports (fruits, vegetables and flowers) has been indicated as a sector that can provide real opportunities for enhancing export performance (Keno, 2011). However, high value horticulture is challenging and the practical risks involved at every stage are so high that the chances of actually attaining such achievements are quite low, and highly dependent on management performance (Joosten *et al*., 2011).

Therefore, production of fresh fruits and vegetables has its own complexity. Their perish-ability and hugeness makes them difficult to manage easily during postharvest period unlike that of dry grains. Because of such perishable nature of the produce and lack of knowledge as well as shortage of capital, horticulture industry in sub-Saharan Africa in general and in Ethiopia in particular stays at its infant stage. The other reason is that most of these perishables are produced by small-scale farmers those who have limited knowledge and financially poor in this region.

Small-scale producers engaged in fruit and vegetable cultivation is estimated at 6.0 million farmers whereas the production estimate of fruit and vegetables, including root crops, is 2.16 million tons (9.2% of total national peasant crop production) in Ethiopia (Joosten *et al*., 2011). This volume is produced on 356 thousand hectares (2.4% of total cultivated land in 2008/09) of peasant holdings. The total fruit and vegetable production comprises about 351 thousand tons of fruits (16%), 600 thousand tons of vegetables (28%), and 1.2 million tons of root crops (56%). Currently 95% of the fresh vegetable supplies to the domestic urban and regional export markets are sourced from the peasant sector in the country.

But small-scale vegetable farms are based on low input – low output production systems (Olayemi *et al*., 2012). The use of improved seeds and agro-chemicals is not common in the small-scale sector. Technical training and extension services on improved crop husbandry techniques are not available. As a result average productivity of the crops is low both in quality and quantity. Losses of agricultural products also occur at all stages in the postharvest chain in the small-scale farming sector of developing countries. Therefore, postharvest loss is very common both during pre- and post-harvest periods which have a negative impact on the food security program of the countries of the region.

Gustavsson *et al*. (2011) stated that food loss and waste reduction is equally important to that of intensive and extensive farming to secure food for a nation. Losses cause less food to be available and therefore contribute to food insecurity. Producing food that will not be consumed also leads to unnecessary CO_2 emissions in addition to loss of economic value of the food produced. The reduction of postharvest losses of agricultural products is, therefore, important to increase food security and availability in the developing countries (Mrema and Rolle, 2002). Kader (2005) also reported that minimizing postharvest losses of horticultural perishables is a very effective way of reducing the area needed for production and/or increasing food availability. Because the extent of losses and wastage that occur throughout the food supply chains is very high. Not only losses are clearly a waste of food but also they represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce recourses such as water (WRI, 1998).

Estimation of the magnitude of losses and waste are still lacking, particularly in developing countries. Generally, FAO (2012) roughly estimated that yearly global quantitative food losses and waste reached at 40–50% for fruits, vegetables and root crops. Olayemi *et al*. (2012) also estimated that as much as 25% and 40% fruits and vegetables, respectively, are lost after harvest and concluded that farmers experienced serious postharvest losses particularly due to poor postharvest handling measures in their study in Nigeria. Therefore, this review intended: (1) to assess the available literatures on the postharvest losses of fresh fruits and vegetables so as to identifying priority areas of the problem; (2) to identify the causes of losses of perishables accordingly in order to show the weight of the problem and its influence on food security and the economy of a country; and (3) to identify the possible strategies that can reduce losses and maintain quality of the commodities during the period.

2. Extent of Postharvest Losses of Fresh Fruits and Vegetables

Postharvest loss has been defined as a measurable quantitative and qualitative loss of a given product at any moment along the postharvest chain (De Lucia and Assennato, 1994) and includes the change in the availability, edibility, wholesomeness or quality of the food that prevents it from being consumed (FAO and UNEP, 1981).

2.1 Qualitative Losses

Kader (2005) reported that qualitative losses such as loss in edibility, nutritional quality, caloric value, and consumer acceptability of the products are much more difficult to assess than quantitative losses. Standards of quality and consumer preferences and purchasing power vary greatly among countries and cultures. For example, elimination of defects from a given commodity before marketing is much less rigorous in developing countries than in developed countries. However, this is not necessarily bad, because appearance quality is often over-emphasized in developed countries.

Vitamin C, one of the quality parameters, is an important antioxidant that can protect cells from cancer causing agents (Nandi and Bhattacherjee, 2005; Hassan *et al*., 2010). Good sources of vitamin C include such horticultural crops as citrus, mango, pineapple, tomatoes and cauliflower. Hassan *et al*. (2010) investigated that vitamin C content in the pulp of mango sharply declined from 51.48 mg/100g at farm fresh level to 17 mg/100g at 8 days after harvest. Tomato is also observed to be a moderate source of vitamin C. According to Hassan *et al*. (2010), vitamin C contents declined with duration of storage. It was observed that the vitamin C contents of tomato declined from 25.29 mg/100 g in farm fresh sample to 12.16 mg/100 at day 8, manifesting a total of 51.91% loss of vitamin C.

2.2 Quantitative Losses

2.2.1 Losses of fresh fruits and vegetables in the global level

Kader *et al*. (2012) reported that about one-third of the food produced is wasted in developed and developing countries which accounts to 1.3 billion tons per year. In medium- and high-income countries, a lot of food is discarded while it is still suitable for human consumption (more than 40% of the losses occur at the retail and consumer levels) while in developing countries, food losses occur early in the food supply chain at postharvest and processing stages (Table 1).

According to Salami *et al*. (2010), about 30-40% of fruits and vegetables are lost or discarded after leaving the farm gate. Kader (2002) also estimated that postharvest losses in fresh fruits and vegetables are 5 to 35% in developed countries and 20 to 50% in developing countries. Fresh fruits and vegetables are wasted throughout the food supply chains, from initial agricultural production down to final household consumption (Table 1).

As shown in the table 1, losses at the agricultural production stage exceeds all the other stages in the three industrialized regions (Europe, North America & Oceania and Industrialized Asia), which may mostly due to quality standards set by retailers. Waste at the end of the food supply chains (FSC) is also significant in the three regions, with 15-30% of purchases by mass discarded by consumers. While in developing regions losses in processing and packaging stage exceeds the other losses throughout the FSC which can be explained by deterioration of perishable crops in the warm and humid climate of many developing countries as well as by seasonality that leads to unsalable gluts. Losses during agricultural production stages are also severe. This might be due to lack of knowledge, technology and shortage of capital.

2.2.2 Losses of fresh fruits and vegetables in the sub-Saharan Africa

Africa remains the continent with greater arable land to feed its growing population and beyond, yet the continent remain the most impoverished in food security (Owusu – Sekyere, 2011). The Sub Saharan Africa (SSA) net food production per annum is within 230 million tons (Gustavsson *et al*., 2011). Greater portions of this amount is lost due to various factors ranging, for example, poor infrastructure, low levels of technology and low investment in the food production systems, pest, inadequate policies, storage, climate and other factors (Andah, 2000; Gustavsson *et al*., 2011). Accordingly, the loss of fresh fruits and vegetables can be estimated based on the data of Gustavsson *et al*., 2011 (FAO) (Figure 1).

2.2.3 Estimation of losses of fresh fruits and vegetables in Ethiopia

Currently there are limited literatures to review on the extent of postharvest losses of fresh fruits and vegetables in Ethiopia due to lack of research works in the sector. However, it is possible to estimate such losses of these perishables based on the annual production data of central statistics agency (CSA) of the country. Accordingly, about 192,555.39 and 4,793,360.64 hectares of land were under production of vegetables and fruits, respectively, during the main production season (2012/13) (CSA, 2012/13). According to the rough estimation of FAO (2012), yearly global quantitative food losses and waste reached at 40–50% for fruits, vegetables and root crops. From this estimation, the following values shown in table 2 are losses which can be occur from yearly production of some fruits and vegetables grown in Ethiopia.

Householders living near to urban centers largely practice vegetable farming. Most vegetables are not commonly practiced by the rural private peasant holders hence the small volume of production recorded as well evidenced by the survey results of CSA (2012/13). Vegetables took up about 1.43% of the area under all crops at national level in 2012/13 production year. Of the areas under vegetables, 71% and 18% was under red peppers and Ethiopian Cabbage, respectively. Production of vegetables contribute 2.95% of the total crops production, conversely, of the total production of vegetables, red pepper and Ethiopian Cabbage have the lions share, *i.e.* about 37.14% and 43.53% (CSA, 2012/13).

According to CSA (2012/13), bananas, mangoes, papayas and oranges took up 63%, 15%, 8% and 8% of the fruit production in the country, respectively, (Table 2.5). More than 479,337 tons of fruits were produced in the country during the production year of (2012/13).

2.3 Impact of the Losses

2.3.1 Economic impacts

Food loss and wastage have many negative impacts on economy and environment. Economically, they equate to a wasted investment that reduces the economic wellbeing of actors in the food value chain. For example, food waste at the consumption stage costs an average of US$1,600 per year for a family of four in the United States and about US$1,000 per year for the average household in the United Kingdom (Lipinski *et al.,* 2013). In china, about US$32 billion worth of food is thrown away annually (WRAP, 2011; Zhou, 2013). In Sub-Saharan Africa, where many farmers earn less than US$2 a day, postharvest losses have a value of up to US$4 billion per year (World Bank, NRI and FAO, 2011).

As a consequence, food losses and waste have impacts on hunger and poverty alleviation, nutrition, income generation and economic growth. Food losses are indicative of poorly functioning and inefficient value chains and food systems, and as such they represent a loss of economic value for the actors in these chains. Food commodities traded at international markets and wasted in one part of the world could affect food availability and prices in other parts.

2.3.2 Impact on the environment and climate

Food losses and waste have also negative impacts on the environment because of the energy, biodiversity, greenhouse gases, water, soil and other resources embedded in food that no one consumes. Producing food that will not be consumed leads to unnecessary CO_2 emissions in addition to loss of economic value of the food produced. Producing food that will not be consumed leads to unnecessary CO_2 emissions in addition to loss of economic value of the food produced (Gustavsson *et al*., 2011).

Environmentally, food loss and waste represent unnecessary greenhouse gas emissions and wasted water and land. Globally, the amount of food loss and waste in 2009 was responsible for roughly 3,300-5,600 million metric tons of greenhouse gas emissions (carbon dioxide equivalent), the upper end of which is almost equivalent to the amount of carbon dioxide emissions from energy consumption by the United States in 2011 (Lipinski *et al.,* 2013). Food loss and waste are associated with approximately 173 billion cubic meters of water consumption per year, which represents 24 percent of all water used for agriculture (Kummu *et al.,* 2012). The amount of cropland used to grow this lost and wasted food is 198 million hectares per year, an area about the size of Mexico (Kummu *et al.,* 2012). And 28 million tons of fertilizers are used annually to grow this lost and wasted food (Kummu *et al.,* 2012). Beyond these quantified impacts, natural landscapes and the ecosystem services they provide are also adversely affected by the resources that go into producing this lost and wasted food.

3. Causes of Postharvest Losses in Fresh Fruits and Vegetables

Causes of food loss are varying between developing and developed countries due to economic growth. Accordingly, Gustavsson *et al.* (2011) stated that the causes of food losses and waste in developed countries mainly relate to consumer behavior as well as to a lack of coordination between different actors in the supply chain. Farmer-buyer sales agreements may contribute to quantities of farm crops being wasted. Food can be wasted due to quality standards, which reject food items not perfect in shape or appearance. At the consumer level, insufficient purchase planning and expiring also cause large amounts of waste together with the careless attitude of those consumers who can afford to waste food.

The causes of food losses and waste in developing 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. Physical and quality losses are mainly due to poor temperature management, use of poor quality packages, rough handling, and a general lack of education regarding the needs for maintaining quality and safety of perishables at the producer, wholesaler, and retailer levels (Kitinoja *et al*., 2010). Consequently, the following are among the most important causes of losses for the fresh fruits and vegetables in developing countries in general and sub Saharan Africa in particular.

3.1.1 Poor temperature management

Temperature in both extremes is the main causative agent in affecting the postharvest period of horticultural perishables. Thus, amount of temperature in the horticultural produce during harvesting, handling, transport and marketing is much higher than those recommended for quality maintenance of the produce due to continuous and high rate of respiration and other related biochemical reactions of the produces. For example, pulp temperatures for tomatoes in Rwanda were 15.1, 7.1 and 8.4°C higher than recommended when measured at the farm, wholesale market and retail market, respectively, (Kitinoja and AlHassan, 2012). Recommended verses measured pulp temperatures for tomatoes at farm, wholesales market and retail market sites of four countries were reported by Kitinoja and AlHassan (2012) as shown in the table 6, and pulp temperatures for the other crops are all similar to that reported for tomatoes.

The general lack of use of shade contributes to high pulp temperatures and high water losses. For a few crops, pulp temperatures were lower than air temperatures (tomatoes being packed under shade in India, pineapples handled in the early morning in Rwanda, damaged cabbages in Ghana, observed to be wilting in the sun) (Kitinoja and AlHassan, 2012).

High temperatures are well known to result in increased rates of respiration, deterioration and water loss in fresh produce, leading to reduced market value and decreased nutritional value. Measured air and pulp temperatures in SSA and India were so much higher than the optimum postharvest handling temperatures recommended for maintaining optimum quality (Hardenburg *et al*., 1986) that shelf life theoretically would be only one half or even one quarter of the potential.

3.1.2 Mechanical injury

To keep fruits and vegetables fresh during distribution is the main problem. Because, fresh fruits and vegetables are rich of water, easily spoiled and have short shelf life, which largely limit the transportation and transaction time. Therefore, they require highly safety transportation and infrastructure efficiencies. However, due to the undeveloped distribution facilities and equipment the loss of quality is high during distribution and sales process as a result of mechanical injury. According to statistics, the loss rate of fruits and vegetables reaches to 25% to 35%, while the loss rates are respectively blow 5% in developed countries, *e.g.* 1% to 2% in United States (Fang, 2002). According to the other survey report on supermarket fresh logistics distribution centers in 2006, loss of fruits and vegetables mainly lies in processes of transportation, sorting, storage and shipping (Zhang and Deng, 2012).

Kitinoja and AlHassan (2012) further reported that physical damage during handling was very high. Physical damage was even higher for the most delicate crops (*i.e.*, 34.3±40.3% on farm, 86.4±35.9% at wholesale and 73.8±26.0% at retail markets for leafy greens in Benin), for crops handled in a large sack that does not provide protection (*i.e.*, cabbage in Ghana), or without any kind of package (8.5±12.7% on farm, 19.0±18.4% at wholesale and 22.0±14.4% at retail markets for bananas in Rwanda). According to the authors, visual symptoms of losses and quality problems included wilting for leafy greens, softening in fruit crops, and bruising for many of the crops.

For seven crops, adequate data were collected on market prices and price per kg that enabled calculation of the changes in retail market value caused by a decline in visual quality. For both amaranth leaves in Benin and pineapples in Rwanda, economic losses were estimated at 30%, based on reduction in market value per kg of the produce sold when compared to the highest price per kg offered for higher quality produce on the same day in that market. In India, average losses in market value at the retail level as result of perceived decline in quality was 1% for tomatoes, 52% for cucurbits, 31% for okra, 20% for mangoes and 18% for litchis (Kitinoja and AlHassan, 2012).

3.1.3 Microbial action

Agrios (2005) reported that Postharvest diseases destroy 10 to 30% of the total yield of crops, and in some perishable crops, especially in developing countries, they destroy more than 30% of the crop yields. Especially fresh fruits and vegetables are highly perishable products; and their quality is affected by postharvest handling, transportation, storage and marketing. The improper handling, packaging, storage and transportation may result in decay and production of microorganisms (Fig. 4), which become activated because of the changing physiological state of the fruits and vegetables (Wilson *et al*., 1995).

Fungi are the most important and prevalent pathogens infecting a wide range of host plants and causing destructive and economically important losses of most fresh fruits and vegetables during storage and transportation (Sommer, 1985). Fruit, due to their low pH, higher moisture content and nutrient composition are very susceptible to attack by pathogenic fungi, which in addition to causing rots may also make them unfit for consumption by producing mycotoxins (Moss, 2002).

3.1.4 Poor packaging

As reported by Kitinoja and AlHassan (2012), packages used for handling of fresh produce in SSA and India were too big, too rough, and too weak to provide protection for fresh produce during handing and transport (Fig. 5 and 6). Across all crops and countries package protection ratings were uniformly low, 46% of crops were packed in large sacks or cloth bundles, 31% were packed in open baskets and 8% had no package at all. Even some of the most delicate, highly perishable crops were packed in sacks (*i.e.*, leafy greens in Rwanda, okra in India), and many moderately perishable crops were packed in large sacks (eggplant in India, peppers in Ghana and Benin, pineapples in Rwanda).

Kitinoja and AlHassan (2012) additionally reported that only 15% of crops were packed in plastic or wooden crates, and even these containers were of inferior quality. The plastic crates used in India for mangoes and tomatoes were dirty and rough on the inside, causing abrasions, and wooden crates used for tomatoes in Ghana were made with no vents and for holding 60 to 70 kg of ripe fruits. These wooden crates were too large to provide protection, and much of the fruit on the bottom of the crates was crushed and typically discarded before sale.

4. Postharvest Loss Reduction Strategies in Fresh Fruits and Vegetables

4.1 Appropriate Postharvest Technologies for Small Scale Farmers

4.1.1 Improved containers or packages

In India, Saran *et al*. (2012) field tested the locally made and found to be inexpensive, reusable for several uses, and recyclable lightweight corrugated fiber-board liners for cartons and plastic crates. Accordingly guava was transported over a distance of 50 km in inexpensive plastic crates, both with and without crate liners and no significant change in weight loss % was measured for the two treatments, but bruises were observed in 12.5% of the guavas transported in crates without liners. Saran *et al*. (2012) also worked out cost/benefit and return on investment, and stated its profitability as follows. Fifty sets of liners cost US$ 9.50; market value of the bruised guava fruits fell from US$ 0.8/kg to US$ 0.3/kg, which is immediately profitable. For each 1 MT load (50 crates) of guava fruit transported, the additional profits were US$ 52.60 or 5.5 times the cost of the initial investment. Total returns depend upon the number of times the liners are used for transport. Therefore, adoption and the use of such locally available and low-cost materials in other developing countries, like Ethiopia, is important to save the values of perishables in them till consumption.

4.1.2 Improved field packing methods during harvest

Cabbage in large sacks (holding up to 70 kg) suffered 32% breakage and head splitting, while half sized sacks (approximate capacity 30 kg) resulted in less damage (23% breakage and head splitting) (Saran *et al*., 2012). These authors further investigated that market value of the cabbage was the same for the undamaged heads $US 1.00/kg but damaged heads were discarded as a total loss. In India, farmers reported they sold cling wrapped cauliflower for US$ 0.4/head compared to those unwrapped, which sold for US$ 0.2/head, both of the same weight.

Provision of shade with plastic shelters was another feasible technology to be used by small scale farmers as reported by Saran *et al*. (2012). As a result, weight losses under traditional conditions were 2.5% in 4 hours, compared to 0.5% in 4 hours under shade. Quality sorting and grading, plus the use of improved packages resulted in higher price/kg offered by the buyers coming to the farm.

4.1.3 Low energy cool storage practices (zero energy cool chambers) (ZECC)

According to Roy's presentation, [Online] Available: http://www.win2pdf.com, the main advantages of this on-farm low cost cooling technology are: (1) it does not require any electricity or power to operate, and (2) materials required like bricks, sand, bamboo *etc* are available, easily and cheaply. Cool chambers can also reduce temperature by 10-15 ^{o}C and maintain high humidity of about 95% that can increase shelf life and retain quality of horticultural produce (Tables 8 & 9 and Fig. 7).

Packing trials conducted during the cool winter season with spinach resulted in a reduction of weight loss from 5% (no shade) to 1% (under shade) (Saran *et al*., 2012). Poly net shade structures cost US$ 140 each. Although market value for the spinach was the same US$ 0.2/kg, the earnings were higher because of the higher volume available for sale by weight. Differences in weight loss would be higher for trials conducted during the hot summer months.

During the peak of tomato production season in India there is a market glut, and prices offered to farmers fall to UD$ 0.04/kg, while during the lean season the market price can climb as high as US$ 1/kg. Field trials documented that 10 kg of tomato fruit yielded 6 L of juice, which was processed to 2 L of puree. Concerns with traditional chemical treatments (food safety) mean training should be provided on recipe modifications, carefully measuring ingredients, choosing safe alternatives to dangerous chemicals used as food preservatives.

4.2 Use of Solar Drying in Tropical and Subtropical Regions

The best way of maintaining the nutritional value of fruits is by keeping the products fresh. However, most of the storage methods require low temperatures, which are difficult to maintain throughout the chain mainly in the developing countries (Sagar and Kumar, 2010). Wakjira (2010) also reported that other low input approaches include using the abundant solar heat available in tropical and subtropical regions to preserve a greater proportion of locally grown fruits and create other food products from them. Solar drying of fruits is one of these technologies, which can enhance the shelf life of fruits. Besides, it improves nutritional standards in diets, minimize seasonal gluts, and reduce transportation cost.

Fresh produce contains up to 95 % water and thus is sufficiently moist to support both enzyme activity and growth of microorganisms (FAO, 1989). The aim in drying is to reduce the water content of the produce to a level insufficient for enzyme activity or the growth of microorganisms. Depending on the commodity, the critical level is about 10 – 15 percent moisture, because removal of too much water may make the product become brittle and shatter easily (FAO, 1989).

According to Ofor and Ibeawuchi (2010), the products that are used for drying are generally the surplus of fresh fruit and vegetables not consumed at harvest time. In many parts of Ethiopia that have a prevailing dry atmosphere, sun-drying by open tray method is feasible without the use of solar drying structures (Samunegus, 1985; Ofor and Ibeawuchi, 2010). Vegetables in these areas have been reduced to about 10% moisture content by sun-drying, which ensured that they could be stored at moderate temperatures for about 18 months. But fruits have an average shelf life of 7 to 36 days at average storage temperatures (Anonymous, 1991).

4.3 Other postharvest loss reduction strategies

4.3.1 Hot water treatment

Treating of some horticultural commodities is also important to reduce the spread of microbes during distribution and storage. Dea *et al*. (2008b) reported that the hot water quarantine treatment (diping in 46 ^{o}C water for 65 to 110 minutes depending on cultivar and fruit size) of whole mangoes does not significantly affect the quality of fresh-cut 'Kent' mango slices stored at 5 ^{o}C. Ngarmsak *et al*. (2005) reported that washing whole 'Chok Anun' mangoes in warm (50 ^{o}C) or cold (12 ^{o}C) chlorinated (100 ppm) water for 5 minutes significantly reduced total microbial populations on the skin and stem end of the mangoes. These authors further stated that microbial populations on fresh-cut mango slices prepared from unwashed fruit were significantly higher than those prepared from washed fruit immediately following preparation and after 7 days at 5 ^{o}C.

4.3.2 Calcium treatments for firmness retention

As per description of Chantanawarangoon (2000) based on his work on mango, shelf life of fresh-cut mango cubes was limited by softening and browning. At 5 °C, shelf lives of mango cubes treated with distilled water (control), 0.5% $CaCl_2$ and 1% $CaCl_2$ for about 5, 7 and 9 days, respectively. Accordingly, mango cubes treated with 1% $CaCl_2$ had higher flesh firmness and calcium content than those treated with 0.5% $CaCl_2$ or water (control). Chantanawarangoon (2000) concluded that firmness of mango cubes in all treatments decreased during storage. However, firmness of mango cubes treated with 1% $CaCl_2$ was significantly higher than those treated with 0.5% $CaCl_2$ or water (control).

4.3.3 Use of ethylene action inhibitors

Waxing, low O_2, high CO_2 and ripening inhibitors are now and then combined to prolong storage life (Izumi and Watada, 1994; Tessema, 2013). Conversely, optimum treatments for each ripening inhibition, endogenous ethylene (C_2H_4) are always a problem (Tessema, 2013). Thus, many chemical formulations have been tried to keep the ethylene below the threshold level. Ethylene absorbents, such as calcium chloride ($CaCl_2$) and potassium per manganent ($KMnO_4$), in conjugation with controlled storage atmosphere have a notable commercial potential which may not feasible for the small scale farmers.

The results of chemical treatment trial, by Tessema (2013), indicated that spoilage of tomato fruits was increased in all the treatments over storage time (Table 4.1). However, there was a difference in magnitude spoilage between and within the treatments. According to Tessema (2013), the least spoilage (22.5%) was recorded in fruits treated with 8% $CaCl_2$ and packed with ventilated polythene cover whereas maximum (100%) spoilage was recorded on the treatments which were not under modified atmosphere at end of the fourth week (Table 10). This indicated a significant role of $CaCl_2$ as an ethylene absorbent and this aspect together with modified atmosphere could have less extent of spoilage on storage period.

Plotto *et al.* (2003) also investigated that the effects of treating whole 'Kent' mangoes with 1-methylcyclopropene (1-MCP, 25ppm), heat (38 ^{o}C and 98% relative humidity for 12 or 24 hours), or ethanol (5 g/kg) on quality and shelf-life of fresh-cut pieces. The fresh-cut pieces were dipped in 2% calcium ascorbate and 1% citric acid to prevent browning. They found that the 1-MCP and heat treatments decreased firmness while the ethanol treatment maintained firmness similar to the control. After 12 days at 7-8 ^{o}C, cut pieces from ethanol-treated mangoes maintained the best visual quality, but had off-flavor. Similarly, Vilas-Boas and Kader (2007) found that softening and browning were delayed when 1-MCP (0.5 or 1.0 ppm for 6 hours) was applied directly on fresh-cut 'Kent' and 'Keitt' mango slices.

5. Summary and Conclusion

It is obvious that the loss of fresh fruits and vegetables (perishables) in the postharvest supply chains is common in both developed and developing countries and not new, and it has been continuing as a major problem for mankind. In addition to that, currently human population is increasing rapidly and also climate change brings additional complications in the developing countries of the world where technology is insufficient and food is already short. Therefore, urgent solution is required to supply food continuously both in quality as well as in quantity to mankind in order to alleviate hunger and malnutrition. This can be okay through application of intensive and/or extensive farming along with proper management of produced food commodities during postharvest period. The main objective of this review is, therefore, to assess literatures on the extents and causes of postharvest losses of perishable crops, mainly fresh fruits and vegetables. Thus, the manuscript examined the importance of perishable crops; the various concepts of postharvest food losses of perishables in the global, sub Saharan Africa and Ethiopian levels. Postharvest loss reduction strategies are also assessed.

According to the UN projects, world population will grow from its current 6.8 billion to 9.1 billion in 2050. Feeding this larger and more urban population will require agricultural production to grow by 70 per cent as said by FAO. This huge increase in demand will not be achieved through increasing food production as usual. This is particularly because of the resources for producing food is becoming increasingly scarce. Reducing food losses by addressing inefficiencies across the entire food supply chain must thus be an essential component of any strategy to make more food available without increasing the burden on our natural environment. Unfortunately, this is an area that has been neglected over the years. Less than 5 per cent of funding for horticultural research and extension has been allocated to postharvest issues over the past 20 years, as the historical focus has been on increasing production.

With postharvest issues having been largely ignored, a firm evidence base from which to assess global food waste is lacking. Much of the data on losses have not been collected systematically and updated. In addition, there has not been much research on the impact of food waste in transitional countries such as Ethiopia. Therefore, there is an urgent need for more quantitative research providing loss estimates for the food supply chains of developing countries and the rapidly evolving transitional countries. Without such evidence, discussions on the potential for reducing global food waste as a contribution to feeding 9 billion by 2050 will remain largely theoretical and measuring progress against any global reduction target almost impossible.

It was reviewed in the literature that the factors contributing to these food losses include; genetic factors, the initial quality of the crop, environmental influence (temperature, relative humidity, and storage atmosphere), mechanical injury. In order to minimize these problems, the appropriate and feasible agricultural techniques such as the general principles of extending shelf-life of these crops must be put in place. There should be selection of appropriate varieties, following of proper harvesting and handling, proper management of temperature, humidity and effective methods for preventing these losses. Since most national governments acknowledge that postharvest food losses is complex, therefore, it requires a commitment to an integrated approach, involving numerous organizations, including local communities and groups especially those involved into the food supply chains.

The food supply chains in developing countries need to be strengthened by, encouraging small farmers to organize and to diversify and scale up their production and marketing. Investments in infrastructure, transportation, food industries and packaging industries are also required. Both the public and private sectors have a role to play in achieving this.

6. References

Agrios, G.N. (2005), Plant Pathology. 5th eds. Elsevier Inc. Academic Press, USA. 553p.

Andah, A. (2000), Technological transitions: Technical upgrading of indigenous food technologies in Africa, ECA - Food Security and Sustainable Development Division. Available at: http://www.un.org/depts/eca/divis/fssd/

Anonymous, (1991), Shipping Guide for Perishables. Sealand corporate marketing. Edison, New Jersy. 1-28p.

Buzby, J.C. and Hyman, J. (2012), Total and per capita value of food loss in the United States. *Food Policy*, 37:561–570.

Chantanawarangoon, S. (2000), Quality maintenance of fresh-cut mango cubes. M.S. thesis in Food Science, University of California at Davis. 72p.

De Lucia, M. and Assennato, D. (1994), Agricultural engineering in development: Postharvest operations and management of food grains. FAO Agricultural Services Bulletin No. 93. Rome: FAO.

Dea, S., Brecht, J.K., Nunes, M.C.N. and Baldwin. E.A. (2008b), Quality of fresh-cut 'Kent' mango slices prepared from hot-water or nonhot-water-treated fruit. *HortScience*, 43:1210. (*Abstract*).

Fang, X. (2002), Why traders laugh in middle and cry at both ends in Agricultural Logistics. International Trade News, 001.

FAO (Food and Agricultural Organization) (1989), Prevention of Post-Harvest Losses Fruits, Vegetables and Root Crops: A Training Manual Smith, K. (eds.). Series: no 17/2. Food and Agricultural Organization of the United Nations, Rome, 1989.

FAO (Food and Agriculture Organization of the United Nations) (2009), How to Feed the World in 2050, Rome. [Online] Accessible: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

FAO and UNEP (1981), Food Loss Prevention in Perishable Crops. FAO Agricultural Services Bulletin No. 43. Rome: FAO.

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A. (2011), Global Food Losses and Food Waste: Extent Causes and Prevention, Rome, Food and Agriculture Organization (FAO) of the United Nations.

Hassan, M.d.K., Lal Das Chowdhury, B. and Akhter, N. (2010), Post Harvest Loss Assessment: A Study to Formulate Policy for Loss Reduction of Fruits and Vegetables and Socioeconomic Uplift of the Stakeholders. Final Report PR #8/08. 118-126p.

Izumi, H. and Watada, A.E. (1994), Calcium treatments affect storage quality of shredded carrots. *Journal of Food Science*, 59(1): 106-109.

Joosten, F., Boselie, D., Bekele, W. and Lemma, D. (2011), Assessment of development potentials and investment options in the export-oriented fruit and vegetable sector. Ethiopian Horticultural Producers and Exporters Association and Ethiopian Horticultural Development Agency. 13-17p.

Kader, A.A., Kitinoja, L., Hussein, A.M., Abdin, O., Jabarin, A. and Sidahmed, A.E. (2012), Role of Agro-industry in Reducing Food Losses in the Middle East and North Africa Region.

Kader, A.A. (2005), Increasing Food Availability by Reducing Postharvest Losses of Fresh Produce. Pp. 2169-2176. Proc. 5th Int. Postharvest Symp. Eds. F. Mencarelli and P. Tonutti Acta Hort. 682, ISHS 2005. USA.

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

Keno, K., (2011), Center for Regional and Local Development Studies Challenges and Opportunities of Horticulture Industry and Its Contribution to the Ethiopian Export Diversification: The Case of Sebeta Area Farms, Finfinne Surrounding Special Zone. An MSc Thesis Presented to the School of Graduate Studies of Addis Ababa University. 1-50p.

Kereth, G.A., Lyimo, M., Mbwana, H.A., Mongi, R.J. and Ruhembe, C.C. (2013), Assessment of Post-harvest Handling Practices: Knowledge and Losses of Fruits in Bagamoyo District of Tanzania. *Food Science and Quality Management*, 11: 8-15.

Kitinoja, L, AlHassan, H.A., Saran, S. and Roy, S.K. (2010), Identification of appropriate postharvest technologies for improving market access and incomes for small horticultural farmers in sub-Saharan Africa and South Asia. Invited paper in three parts for the IHC Postharvest Symposium Lisbon, August 23. *Acta Hortic* (in press). 597p.

Kitinoja, L. and AlHassan, H.Y. (2012), Identification of Appropriate Postharvest Technologies for Small Scale Horticultural Farmers and Marketers in Sub-Saharan Africa and South Asia - Part 1. Pp. 31-40. *In*: M.I. Cantwell and D.P.F. Almeida (Eds.). Postharvest Losses and Quality Assessments. Proc. XXVIIIth IHC – IS on Postharvest Technology in the Global Market Acta Hort. 934, ISHS.

Kummu, M., de Moel, H., Porkka, M., Siebert, S., Varis, O. and Ward, P.J. (2012), Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertilizer use. *Science of the Total Environment*, 438: 477-489.

Labaste, P. (2005), The European Horticulture Market. Opportunities for Sub-Saharan African Exporters. Working Paper No. 63, Washington: The World Bank.
Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R. and Searchinger, T. (2013), Reducing Food Loss and Waste. Working Paper, Installment 2 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute. 8-9p. [Online] Available: http://www.worldresourcesreport.org. (June 11, 2013).
Moss, M.O. (2002), Mycotoxin review. 1. Aspergillus and Penicillium. *Mycologist*, 16: 116-119.
Mrema, C.G. and Rolle, S.R. (2002), Status of the Postharvest Sector and Its Contribution to Agricultural Development and Economic Growth. Proceeding of the 9th JIRCAS International Symposium, (JIRCAS-08), Value-Addition to Agricultural Products, Ibaraki, Japan. 13-20p.
Nagayets, O. (2005), Small farms: current status and key trends. Information brief prepared for the future of small farms research workshop. International Food Policy Research Institute: Wye College, Washington DC.
Nandi, B.K. and Bhattacharjee, L. (2005), Why Fruits and vegetables? Their contribution to improving nutrition in developing countries. Paper presented at the FAO Sub Regional Workshop on Quality and Safety of Fresh Fruits and Vegetables (28 February to 4 March 2005).
Ngarmsak, M., Ngarmsak, T., Ooraikul, B., Delaquis, P.J., Toivonen P.M. and Mazza, G. (2005), Effect of sanitation treatments with heated, chlorinated water on the microbiology of fresh-cut Thai mangoes. *Acta Hort*., 682:1895-1899.
Ofor, M.O. and Ibeawuchi, I.I. (2010), Sun-drying - A low cost Technology for Reducing Postharvest losses. *Academia Arena*, 2(1):56-59.
Olayemi, F.F., Adegbola, J.A., Bamishaiye E.I. and Aawagu, E.F. (2012), Assessment of postharvest losses of some selected crops in eight local government areas of rivers state, Nigeria. *Asian journal of rural development*, 2(1): 13-23.
Owusu – Sekyere, B.N. (2011), Commercialization of food processing and preservation in Africa: The need for outcome-based policy imperatives to impact job creation, regional and local economic growth and ensuring consumers' safety. A Paper Presented at the Sustainable Agricultural Development and Food Security Summit 2011on 29 – 31 August 2011, Southern Sun Grayston Hotel, Sandton, Johannesburg, South Africa.
Plotto, A., Bai, J., Baldwin, E.A. and Brecht, J.K. (2003), Effect of pretreatment of intact 'Kent' and 'Tommy Atkins' mangoes with ethanol vapor, heat or 1-methylcyclopropene on quality and shelf-life of fresh-cut slices. *Proc. Fla State Hort. Soc.*, 116:394-400.
Roy. n. d. "On-farm storage technology can save energy and raise farm income." Presentation. [Online] Accessible: http://www.win2pdf.com. (February 12, 2013).
Sagar, V.R. and Kumar, S.P. (2010), Recent advances in drying and dehydration of fruits and vegetables: A review. *J. Food Sci. Technol*., 47(1): 15-26.
Salami, P., Ahmadi, H., Keyhani A. and Sarsaifee, M. (2010), Strawberry post-harvest energy losses in Iran. *Researcher,* 4: 67-73.
Samunegus, H.M. (1985), Production of Sun-Dried Products for Local Distribution by Development of an Integrated Technology in Ethiopia. In: Expert Consultation on Planning the Development of Sun-drying Techniques in Africa. Food and Agricultural Organization of the United Nations, Rome.
Saran, S., Roy, S.K. and Kitinoja, L. (2012), Appropriate Postharvest Technologies for Small Scale Horticultural Farmers and Marketers in Sub-Saharan Africa and South Asia – Part 2. Pp. 41-52. *In*: M.I. Cantwell and D.P.F. Almeida (Eds.). Field Trial Results and Identification of Research Needs for Selected Crops. Proc. XXVIIIth IHC – IS on Postharvest Technology in the Global Market Acta Hort. 934, ISHS.
Sommer, N.F. (1985), Strategies for control of post-harvest disease of selected commodities. In: Post-harvest Technology of Horticultural Crops. University of California Press. 83-98p.
Spencer, D. (2002), The future of agriculture in sub - Saharan Africa and South Asia; whither the small farm? In: Sustainable Food Security for All by 2020. Proceedings of an International Conference, Sept 4 - 6 2001 Bonn Germany. IFPRI.
Tessema, G. (2013), Effect of Post Harvest Treatments on Storage Behavior and Quality of Tomato Fruits. *World Journal of Agricultural Sciences*, 9 (1): 29-37.
The Federal Democratic Republic Of Ethiopia, Central Statistical Agency (2013). Agricultural Sample Survey Report On Area And Production Of Major Crops (Private Peasant Holdings, Meher Season), Volume I, Statistical Bulletin, No. 532. Addis Ababa. 12-15p.
Tomas-Barberan, F.A. and Espin, J.C. (2001), Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. *J. Sci. Food Agric*. 81:853-876.
Hardenburg, R.E., Watada, A.T. and Wang, C.Y. (1986), The Commercial Storage of Fruits, Vegetables and Nursery Stocks. Agriculture Handbook No 66. US Dept. of Agriculture. Washington DC.
Vilas-Boas, E.V. de, B. and Kader, A.A. (2007), Effect of 1-methycyclopropene (1-MCP) on softening of fresh-cut kiwifruit, mango and persimmon slices. *Postharvest Biol. Technol.* 43: 238-244.
Wakjira, M. (2010), Solar drying of fruits and windows of opportunities in Ethiopia. A Review Paper. *African*

Journal of Food Science, 4(13):790-802.
Wargovich, M.J. (2000), Anticancer properties of fruits and vegetables. *HortScience*, 35:573-575.
World Health of Organization (WHO) (2002), Facts Sheet N° 124: Foodborne Diseases Emerging.
Wilson, L.G., Boyette, M.D. and Estes, G.A. (1995), Post harvest handling and cooling of fresh fruits, vegetables and flowers for small farms leaflets 800 – 804. North Carolina cooperative extension service. 17p.
World Bank, Natural Resources Institute, and FAO (2011), Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. Washington, DC: The World Bank.
Waste and Resource Action Programme (WRAP), (2011), New estimates for household food and drink waste in the UK. [Online] Accessible: http://www.wrap.org.uk/content/new-estimateshousehold-food-and-drink-waste-uk. (June 11, 2013)
World Resources Institute (WRI), (1998), Disappearing food, how big are postharvest losses. World Resources of Institute, Washington, DC., USA.
Zhang, S. and Deng, X. (2012), Fresh fruits and vegetables distribution system in China - Analysis on the feasibility of Agricultural super-docking. 39-41p.
Zhou, W. (2013), Food Waste and Recycling in China: A Growing Trend? [Online] Accessible: http://www.worldwatch.org/food-waste-and-recyclingchina-growing-trend-1. (June 11, 2013)

Table 1. Part of the initial production lost or wasted at different stages of the food supply chain for fruits and vegetables in different regions

Region	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution	Consumption	Total
Europe incl. Russia	20%	5%	2%	10%	19%	56%
North America & Oceania	20%	4%	2%	12%	28%	66%
Industrialized Asia	10%	8%	2%	8%	15%	43%
Sub Saharan Africa	10%	9%	25%	17%	5%	66%
N. Afri, W. & Cent. Asia	17%	10%	20%	15%	12%	74%
Latin America	20%	10%	20%	12%	10%	72%

Source: Gustavsson *et al*., 2011

Table 2. Estimated values of postharvest losses of vegetables in Ethiopia during the production year of 2012/13

Vegetable crops	Area of production (ha)	Total production (ton)	Estimated postharvest losses (ton)
Potatoes	74,934.57	863,347.8	345,339.1-431,673.9
Eth. Cabbage	34,791.05	370,995.2	148,398.1-185,497.6
Red peppers	136,503.7	316,554.1	126,621.6-158,277.0
Green peppers	10,588.52	85,547.8	34,219.1-42,773.9
Tomatoes	7,237.35	55,514.3	22,205.7-27,757.1
Head cabbage	3,049.01	23,224.7	9,289.9-11,612.3
Swiss chard	310.70	329.04	131.6-164.5
Lettuce	75.01	*	*
Total vegetables	**192,555.39**	**852,308.3**	**340,923.3-426,154.1**

Source: CSA, 2012/13; Note that losses are calculated in 40-50% for each commodity. * No data.

Table 3. Estimated values of postharvest losses of fruits in Ethiopia during the production year of 2012/13

Fruit crops	Area of production (ha)	Total production (ton)	Estimated postharvest losses (ton)
Bananas	36,012.2	302,502.2	121,000.9-151,251.1
Mangoes	8,808.64	69,750.7	29,900.3-34,875.3
Papayas	2,752.08	38,694.3	15,477.7-19,347.1
Oranges	2,999.21	35,745.8	14,298.3-17,872.9
Avocadoes	8,938.24	25,633.2	10,253.3-12,816.6
Lemons	754.23	5,516.7	2,206.7-2,758.3
Guavas	1,492.32	1,173.0	469.2-586.5
Pineapples	215.69	*	*
Total fruits	**61,972.6**	**479,336.1**	**191,735.6-239,668.0**

Data source: CSA, 2012/13; Note that losses are calculated in 40-50% for each commodity. * No data.

Table 4. Estimated value of fruits and vegetables loss at the retail and consumer levels in the United States, 2008

Commodity	Food supply	Losses from food supply chain					
		Retail level		Consumer level		Total retail and consumer levels	
	Million dollars	Million dollars	Percent	Million dollars	Percent	Million dollars	Percent
Fruits	***62,146***	***5,795***	***9***	***9,340***	***15***	***15,135***	***24***
Fresh	38,120	4,353	11	7,080	19	11,435	30
Processed	24,026	1,442	6	2,258	9	3,700	15
Vegetables	***103,417***	***9,174***	***9***	***18,493***	***18***	***27,667***	***27***
Fresh	61,039	6,631	11	12,316	20	18,947	31
Processed	42,378	2,543	6	6,177	15	8,720	21
Total	**165,563**	**14,969**	**9**	**27,833**	**17**	**42,802**	**26**

Source: Buzby and Hyman, 2012

Table 5. Estimated per capita value of fruits and vegetables loss at the retail and consumer levels in the United States, 2008

Commodity	Food supply	Losses from food supply chains					
		Retail level		Consumer level		Total retail and consumer levels	
	Dollars	Dollars	Percent	Dollars	Percent	Dollars	Percent
Fruits	***204***	***19.1***	***9***	***30.7***	***15***	***49.8***	***24***
Fresh	125	14.3	11	23.3	19	37.6	30
Processed	79	4.7	6	7.4	9	12.2	15
Vegetables	***340***	***30.2***	***9***	***60.8***	***18***	***91.0***	***27***
Fresh	201	21.8	11	40.5	20	62.3	31
Processed	139	8.4	6	20.3	15	28.7	21
Total	**544**	**49.3**	**9.1**	**91.5**	**17**	**140.8**	**26**

Source: Buzby and Hyman, 2012

Table 6. Recommended verses measured pulp temperatures for tomatoes at farm, wholesale market and retail market sites in four countries

Countries	Recommended temperature	Mean pulp temperatures (^oC) ± st.dev.		
		Farm	Wholesale Market	Retail Market
India	15	25.2±0.6	30.5±2.7	29.1±2.8
Ghana	15	31.2±2.7	30.2±2.5	32.5±2.6
Benin	15	28.5±1.7	29.1±1.2	30.6±2.7
Rwanda	15	30.1±3.0	22.1±1.2	23.4±2.3

Source: Kitinoja and AlHassan, 2012

Table 8. Storage of some fruits in cool chamber

Crop	Cool chamber		Room temperature	
	Shelf life (days)	PLW (%)	Shelf life (days)	PLW (%)
Banana	20	2.50	14	4.80
Grapefruit	70	10.20	27	4.94
Guava	15	4.00	10	13.63
Lime	25	6.00	11	25.00
Mango	9	5.04	6	14.99

Source: Roy. n.d. "On-farm storage technology can save energy and raise farm income." Presentation. Accessible at: http://www.win2pdf.com

Table 9. Storage of vegetables in cool chamber PLW (Physiological Loss in Weight)

Crop	Cool chamber		Room temperature	
	Shelf life (days)	PLW (%)	Shelf life (days)	PLW (%)
Amaranth	3	10.98	<1	49.82
Okra	6	5.00	1	14.00
Carrot	12	9.00	5	29.00
Potato	97	7.67	46	19.00
Mint	3	18.6	1	58.5
Turnip	10	3.4	5	16.0
Peas	10	9.2	5	29.8
Cauliflower	12	3.4	7	16.9

Source: Roy. n.d. "On-farm storage technology can save energy and raise farm income." Presentation. [Online] Accessible: http://www.win2pdf.com

Table 10. Effect of various postharvest treatments on extent of spoilage of tomato fruits (%)

Treatments	Weeks after harvest				
	Initial (day 1)	1st reek (7th day)	2nd week (14th day)	3rd week (21st day)	4th week (28th day)
(T1)4%$CaCl_2$	0	0	33.3	27.3	100
(T2) 8%$CaCl_2$	0	1.7	28.5	54.5	100
(T3) 12%$CaCl_2$	0	0	6.7	0	100
(T4) 4%$CaCl_2$ + *PC	0	0	0	0	27.3
(T5) 4%$CaCl_2$+ *PC	0	0	0	16.7	22.5
(T6) 4%$CaCl_2$+ *PC	0	0	0	20	23.5
(T7) Control (water dip)	0	0	13.3	36.7	100
(T8) PC (without $CaCl_2$)	0	0	6.7	8.3	70

Source: Tessema, 2013
*PC=Polythene cover with six vents

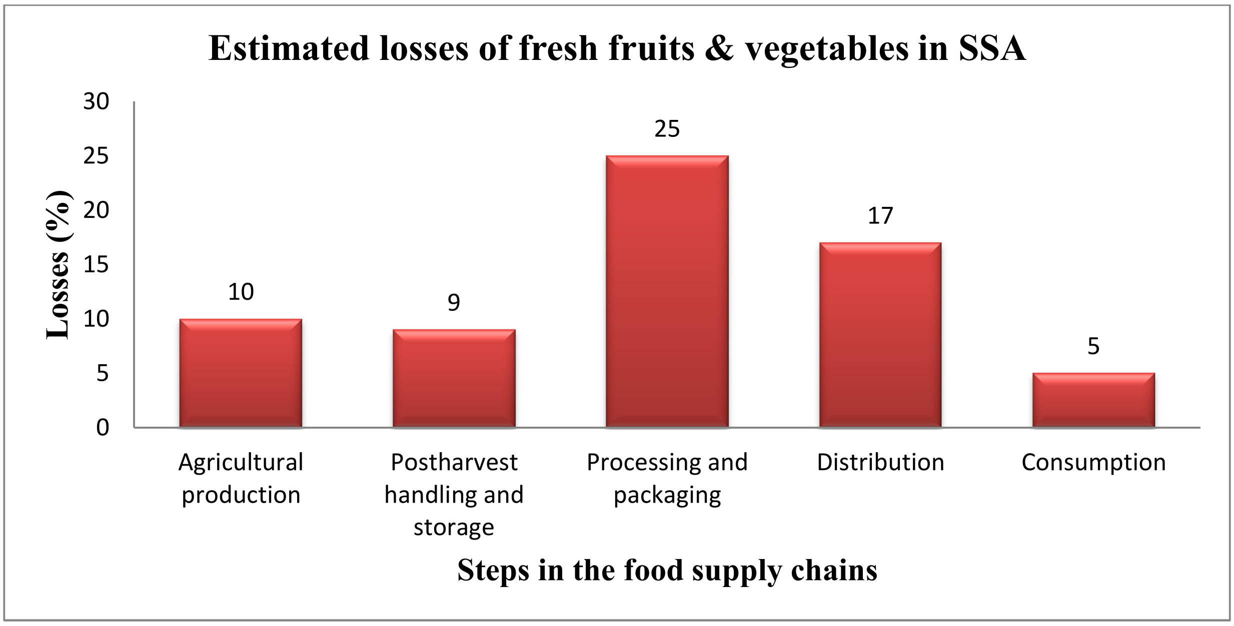


Figure 1. Estimated losses of fresh fruits and vegetables in each steps of the FSC in SSA. **Source:** Gustavsson *et al*., 2011 (FAO)

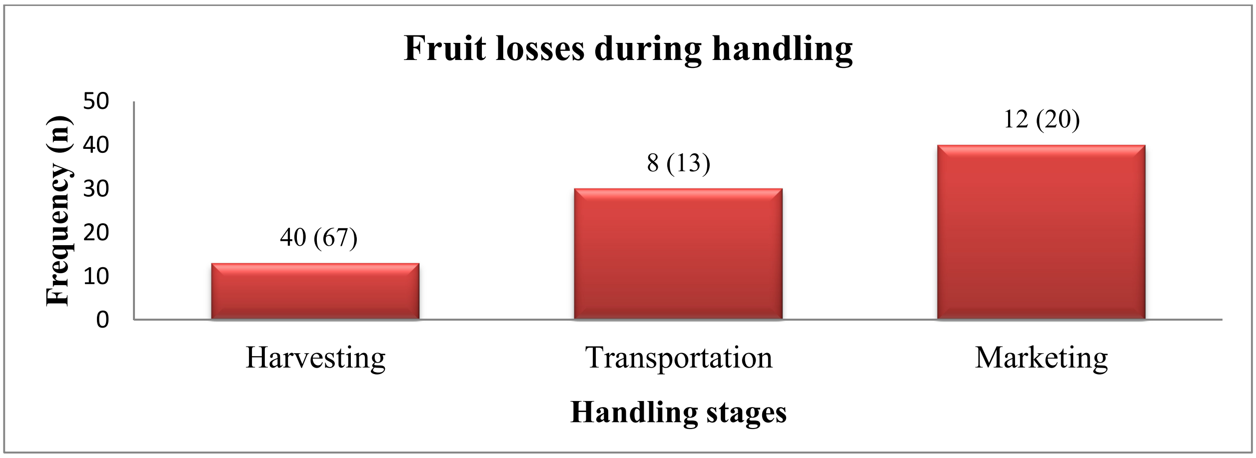


Figure 2. Distribution of respondents according to the type of fruit losses during handling (n=60). **Source:** Kereth *et al*. (2013)

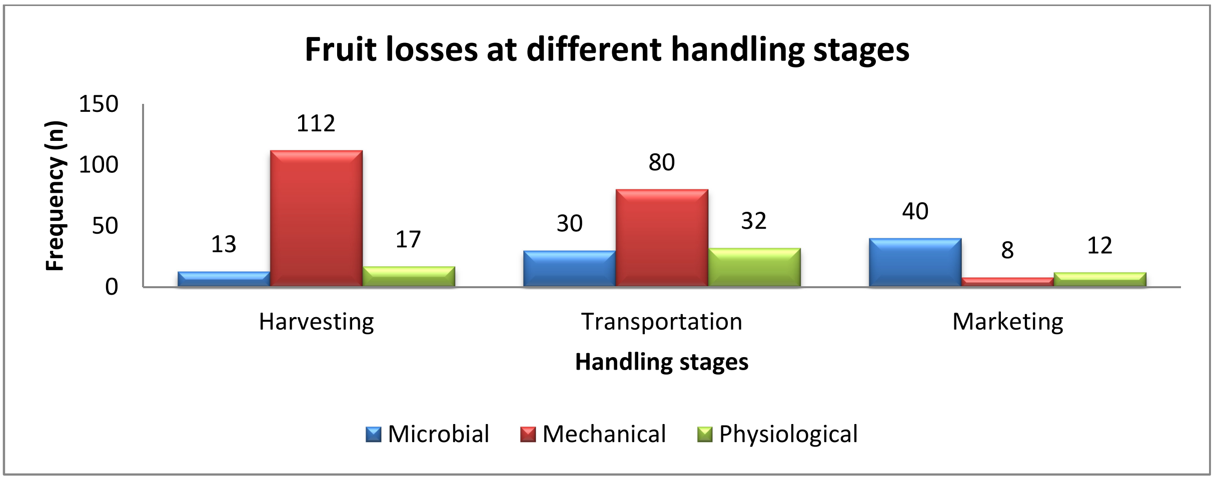


Figure 3. Types and magnitude of fruits losses at various handling stages. **Source:** Kereth *et al*. (2013)

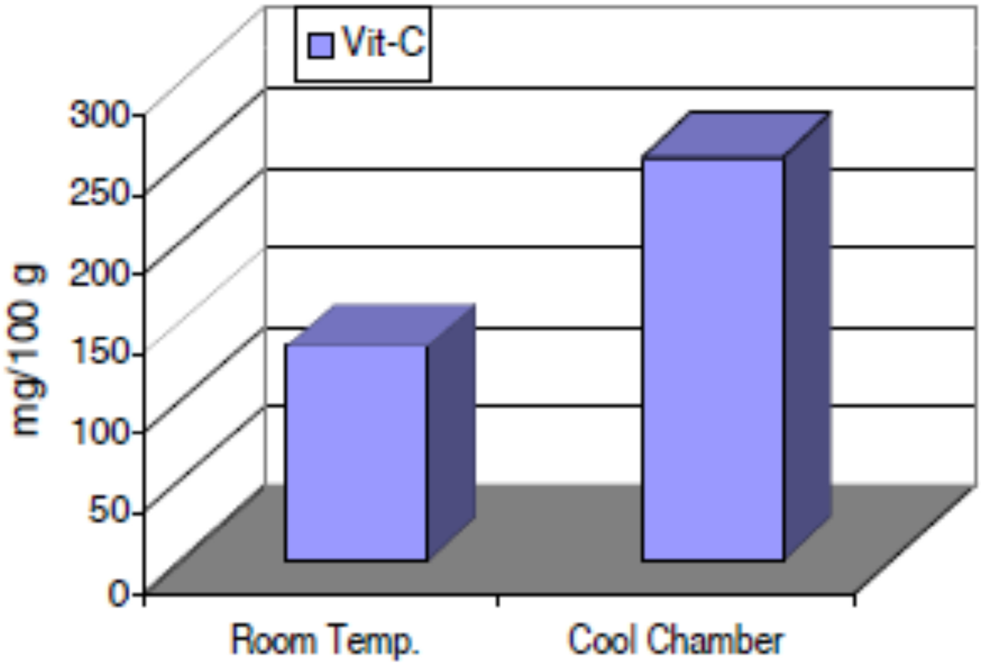
Figure 4. Spoilage due to poor handling. **Source:** Gustavsson *et al*., 2011

Figure 5. Poor quality packages - cloth sacks of eggplant in India (used fertilizer bag). **Source:** Kitinoja and AlHassan, 2012.

(a) (b)

Figure 6. Poor quality packages: – (a) enlarged sacks of cabbage, and (b) huge sized wooden crates of ripe tomatoes in Ghana. **Source:** Kitinoja and AlHassan, 2012.

(a)


Vit-C
mg/100 g
300
250
200
150
100
50
0
Room Temp.
Cool Chamber

(b)


CONTROL
COOL CHAMBER
Kinnows stored at Cool Chamber (60-80 days)
PUSA HYBRID - 2
AMBIENT CONDITION
COOL CHAMBER
Enhance lycopene development (20 days)
Refrigerated
Cool chamber
Room temp.
Spinach stored in cool chamber (3 days)
CONTROL
IRRADIATED
Potato stored in cool chamber (90 days)

(c)

Figure 7. Various uses and benefits of Cool Chamber: (a) Vitamin C maintained in the cool chamber stored tomatoes comparative to room (control) stored ones, (b) Different commodities stored in cool chamber maintain their chemical and appearance qualities, (c) Banana maintain its qualities at the end of 12 days of storage in cool chamber storage. **Source:** Roy. n.d. "On-farm storage technology can save energy and raise farm income." Presentation. [Online] Accessible: http://www.win2pdf.com