World Journal of Agricultural Sciences 17 (4): 328-337, 2021
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2021.328.337

Review on Fruits and Vegetables Post-Harvest Loss in Ethiopia, Factors of Loss and Management Strategies

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Abstract: Fruits and vegetable crops have a significant importance in developing countries identically Ethiopia, in generating income and improving the livelihood and nutrition status of the community domains. The aim of the review is to review post-harvest loss, factors of loss and to generate information and forwarding the management options for the users, farmers, government and all stalk holders. 40-50% of horticultural crops are lost before they can be consumed, mainly because of high rates of bruising, water loss and subsequent decay during postharvest handling in developing countries. Losses were either decreased nutritional quality (loss of vitamins, development of health dangers such as myco-toxins) or reduced market value. Uncontrolled environmental factors like improper handling, unsuitable temperature and relative humidity during storage are the most substantial problems for loss of products both in quality and quantity. Pests and microbial infections are mainly the causes of post-harvest losses of horticultural crops deterioration. From this review it is concluded that there were inappropriate uses of packaging materials, harvesting and handling, storage facilities and transportation to minimize the losses. Therefore, appropriate harvesting technique and time, use of modern storage facilities and food processing techniques are the main tools to reduce food losses and maintain the quality of products.

Key words: Quality Loss · Quantity Loss · Food Waste · Food Loss · Perishable · Horticultural Crops

INTRODUCTION

Horticultural crops are of great economic importance with a prospect for home grown consumption, export markets and processing. Some of the most commonly cultivated horticultural crops in the country were Bananas, avocados, mangoes, citrus, guava, grape, papayas, tomato, onion, carrot and cabbages [1]. EHDA [2] stated that there were inadequate practices of crops which afford vitamins, minerals and dietary fiber in developing countries, like Ethiopia due to small-scale farming systems and unsuitable pre- and post-harvest handling methods. Horticultural crops play a major role in developing country like Ethiopia, both in the in-come generation and social dominions for improving the livelihood and nutrition status of the peoples. In addition, it helps in keeping the ecological balance since horticultural crops species are so various. Also, it gives the employment chances as it requires intensive labor for the management. Production of these crops should be requiring many labors and help to reduces cost of production for capital scarce countries like Ethiopia [3]. Still, the crops form a limited part of the total agricultural produce in the country. Because of the cereal-based food and production practice of the farmers, horticulture was an abused sector. Nevertheless, traditionally different fruits and vegetables, cabbages, inset, pepper, shallot has been produced by small farmers but recently exotic ones are also becoming important in commercial production. Even if, horticultural crops production in Ethiopia has been few ascompared to other crops; currently fruit, vegetable and root and tuber crops are normallyproduced in all regions of the country with different concentration of about an area of 0.55million ha with 60.78 tons of harvest [4].

Vegetables and fruit losses after harvest includes food waste in all points at the supply chain from production in the field to the food being placed on a dish for consumption. Postharvest activities includes harvesting, handling, storage, processing, packaging,

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transportation and marketing [5]. Desta [6] reported that 40-50% of fruits and vegetables produced in developing countries are lost before they can be used, mostly because of high rates of bruising, water loss and subsequent decay during postharvest handling. However, use of appropriate packaging materials, proper storage facilities and transportation can help to minimize these losses. In addition to this, modern food processing techniques and post-harvest technologies are the main tools to reduce perishable food losses and maintain the quality of products [7].

Further, creating efficient, low-cost and native technologies to minimizes post-harvest loss of fruits and vegetables as the largest groups of people in Ethiopia who suffer from food and nutrition insecurity are the rural poor who have insufficient land and lack of resources to provide sufficient income generation through production of fruits and vegetables with integrated post-harvest technology [8, 9]. Therefore, the objective of this review is to know factors of post-harvest losses to generate information and forwarding the management options for the users, farmers and all stalk holders.

Production Status of Fruit and Vegetable in Ethiopia: The commercial production is focused in the Rift Valley areas of Ethiopia, due to accessibility of irrigation facility, convenience and nearness to agro-processing industries. Horticulture Development Corporation of Ethiopian has been thriving the production and marketing activities of horticultural crops since its formation in 1980 [10]. CSA [11] reported that 50, 599.14-hectare of land was covered under fruit and 7, 990.34 hectare under vegetable. Papaya, onion and tomato covered 3, 254.3 ha, 15, 628.44ha and 5, 341.58ha respectively. An annual production of 21, 637, 206.7 quintal was estimated from fruits and 18, 124, 613.5 quintal from vegetable by the same year. Of which papaya, onion and tomato constituted 440, 034.99 Qt, 1, 488, 548.9 Qt and 418, 149.53 Qt respectively. Bananas, papaya, mangoes and orange took up 55.32%, 12.53%, 12.78% and 8.35% of the fruit production, respectively. According to Dawit *et al*. (2004), vegetable crops are produced in the country through commercial and small farmers. The production was varying from cultivating a few plants in the backyards for home consumption up to a large-scale production for domestic and export markets. However, there was a limited domestic market demand for produce that does not meet the high export quality standards (Ethiopian-Netherlands Horticulture Partnership, Mission Report, 2007 but, there was a possibility that a Ministry of Agriculture and Rural Development (MOARD) and donors United State Aid for International Development (US AID) have identified potentials for the further development of fruits and vegetable sector in Ethiopia both for the domestic and export market. Also, in the Ethiopian-Netherlands horticultural Partnership Program, technical support to the development of the fruits and vegetable sector has been prioritized. A number of actors and donors have already started activities in the area of technical production assistance, post-harvest handling and compliance to international standards [12].

From 2002-2006 the Ethiopian government has made a major change in agricultural policies towards the horticultural sector, reflecting efforts to redirect the economy away from centralized planning to a more liberalized economy. The Government increasingly considers the private sector as the engine of economic growth and the catalyst for employment creation and export expansion. As a result, private companies were allowed and facilitated with an array of incentives to engage in the sector [13]. Fruits and vegetables are produced seasonally, but the market requires products throughout the year.

Importance of Fruits and Vegetables for Ethiopian Economy: Horticultural crops offer antioxidants such as vitamin A, C and E that are vital in neutralizing free radicals (oxidants) known to cause cancer, cataracts, heart disease, hypertension, stroke and diabetes [14]. Marketing horticultural crops are of not only important for stimulating production and consumption but also in accelerating the pace of economic development. It leads to the optimization of resource use and output management, increase in farm income, growth of agro based industries, adoption and spread of new technologies, better living and creation of utility. An increase in the efficiency of the marketing process, which results in lower cost of distribution and lower prices to consumers, might bring about an increase in the national income. An efficient marketing system may contribute to an increase in the marketable surplus by scaling down the losses arising out of the inefficient processing, storage and transportation. It guarantees the farmers better prices for their products and induces them to invest their surpluses in the purchase of modern inputs so that productivity may increase [15]. The productions of fruits and vegetables are an important economic activity in Ethiopia, covering from gardening smallholder farming to commercial state and private farms [16].

Table 1: Fruits, Vegetables & Root crops cultivation in Ethiopia for Private peasant Holdings (2010/11)

Crop Type	Area (ha)	%	Production (Quintals)	%	Productivity Qt/Ha
Vegetable	7, 309.16	1.36	1, 403, 234.19	0.63	192
Root Crops	4, 419.64	0.06	996, 331.80	0.45	225.4
Fruit Crops	5, 266.91	0.04	706, 119.18	0.32	134.07

Source? CSA, 2011.

Critical Factors of Fruits and Vegetables Losses: The production of horticultural crops is affected by high temperature, low humidity, wind and flood [17]. FAO [18] reported that post-harvest loss of fruits and vegetables are mainly caused by mechanical, physiological, pathological and environmental factors.

Mechanical Factors

Harvesting: The time of harvest at exact ripening is the main factor that determines the product quality and the shelf-life fruit and vegetables. But some farmers can harvest immature crops due to economic reasons. Unripen fruits are of susceptible to mechanical damage and deterioration and that may cause a poor quality such as high acidity and low sugar through the ripening. On the contrary, over-ripe fruits have a low shelf life. In both cases of over ripening and under ripening the fruits undergo physiological disorders. Harvesting of fruits early reduces the nutritional contents and economic value. In some cases, whole harvested products can be lost because they are not suitable for consumption [19] and methods of harvesting can also cause losses [20]. The losses increase when easily perishable foods such as fruits and vegetables are exposed to more than one treatment. Farmer's lack of storage facilities at the time of harvesting or after harvesting stages also cases losses. That can be leads to mechanical damage during harvesting of fruits, vegetables and root and tuber plants, resulting in certain losses. Improper application of fertilizers, herbicides, fungicides, insecticides, irrigation and pruning in the pre-harvest periods cause fruit and vegetable losses. Also, improper time of harvesting, harvesting methods and practices, failure to apply pre-cooling to fruits like cherries causes the loss up to 4-12% [21, 22].

Environmental Factors: Arah *et al.* [23] review paper indicated that environmental factors such as temperature, humidity, composition and number of gases in controlled atmospheric storage play an important role in post-harvest loss of fruits and vegetables. High temperature and relative humidity service the growth of micro-organisms which result in a serious damage. High temperature also increases the rate of respiration of fruits and vegetables which subsequently result in the breakdown of the inner tissues. Also, high temperature and relative humidity increase the decaying of fruits and vegetables, while decrease in temperature slow down the rate of microbial attack on different crops especially when it is below 5°C. Chilling injury which is caused by low but not freezing temperature is mainly observed with tropical and subtropical fruits and vegetables. However, the symptoms cause by chilling injury may not be evident while the fruits and vegetables are held at chilling temperature but may become visible only when the fruits and vegetables are transferred to room temperature (37°C). Grolleaud [24] reports wind, humidity, rainfall and temperature influence both the quantity and quality fruits and vegetables.

Temperature: Higher temperature shorten the storage life of horticultural produces and causes larger 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. Humidity: There is movement of water vapor between stored food and its surrounding atmosphere until the balance 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 [25].

Altitude: The prevailing temperature within given latitude is dependent upon the altitude when other factors are equal. There is on the average a drop in temperature of 6.5°C for each kilometer increase in elevation above sea level [26]. 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 [27]. 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.

Physiological Factors

Storage: Supplying of a cold chain is a continuous of a product from production to consumption at a certain temperature. Continuous cold chain in perishable food ensures that the product reaches the consumer without deterioration. Effective cold chain management starts with pre-cooling and continues with cold storage, cold transport and refrigerated display cases. The International Refrigeration Institute (IIR) calculated that in developing countries 23% of the perishable foods were spoiled because of not being used the cooler [28]. After application of some treatments such as cleaning, sorting and packaging on post-harvest products, it may be necessary to store the products in periods ranging from a few hours to a few months. By storing products, time management can be improved and marketing and consumption can be done leisurely. Of course, this situation is valid when the storage operation is carried out under suitable conditions; otherwise, serious losses may occur in products.

Nevertheless, it should be remembered that even if the products are stored in the best conditions, the quality and consumables of the products depends on the stage of the whole food supply chain. In developed countries, storage is uniformly provided throughout the entire supply chain from the production stage. When cold storage is combined with post-harvest technology such as a controlled atmosphere, the shelf life of perishable foods become considerably longer. The lack of proper storage facilities in developing countries is seen as the main cause of post-harvest losses [29].

Transportation: Since transportation places a certain period of time between production and consumption, it can be one of the main causes of losses, especially for fresh products. In developed countries, delivery of perishable foods with refrigerated vehicles is a standard practice. Losses in such cases occur when the cooling system in the vehicle is broken down, when an accident occurs or when there is a delay in the loading/unloading areas. In developing countries, the absence of appropriate means of transport, poor roads and inefficient logistics management prevent perishable foods from being properly preserved. In addition, loading and unloading operations are carried out in these countries by unskilled and uneducated workers who generally do not carry products carefully. This causes mechanical damage in agricultural products [30]. In many cases, food products are improperly packaged and loaded and sometimes even they are thrown into vehicles. The poor roads in the rural areas where the majority of the production is made lead to increase in food losses during transportation. Even in rainy times, the getting cars might get stuck in the mud leads to loss.

Improper Packaging: Losses can be largely prevented with timely and accurate harvesting, refrigerated car use in intercity transport, cold storage and use of packaging material that can prevent moisture loss. 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 [31]. Packaging is an important factor in reducing losses, as well as extending the shelf life of fresh fruits and vegetables. Therefore, one of the major reasons that fruits and vegetables are lost at post-harvest stages is improper packaging and use of unsuitable packaging material. Poor quality packaging materials cannot adequately protect the fresh produce from damages and can even accelerate spoilage of fresh produces. Unfortunately, low-quality packaging materials are widely used in many parts of the world due to their low cost. Especially, use of poor-quality packaging container is more common in under-developed and developing countries. Even some of delicate fruit and vegetables are packed in poly-sacks that severely damage to the delicate products. According to a study carried out in some countries in Sub-Saharan Africa and South Asia, 46 % of horticultural crops were packed in cloth bundles or large sacks, 31% of them were packed in open baskets and 8 % had no package at all [32].

Damage in the Marketing Chain: About, 29.8% of the producers were lost their produce due to marketing problems (lack of demand and sanitation) which is followed by injury and infection 18.5% of the yield loss during harvesting, transportation and marketing [33, 34] in developing countries ranges about 20–40% losses, but improper harvesting was the least (15%) loss of fruits and vegetables. Fruits and vegetables are very susceptible to mechanical injury. This can occur at any stage of the marketing chain and can result from poor harvesting practices such as the use of dirty cutting knives; unsuitable containers used at harvest time or during the marketing process, e.g., containers that can be easily squashed or have splintered wood, sharp edges or poor nailing; over packing or under packing of containers; and

Fig. 1: Improper PHM of fruits (Mango) and loss of the produce. (Source: Rahiel *et al*., 2018)

careless handling of containers. Resultant damage can include splitting of fruits, internal bruising, superficial grazing and crushing of soft produce. Poor handling can thus result in development of entry points for moulds and bacteria, increased water loss and an increased respiration rate [35].

Pathological Factors

Microbiological: Micro-organisms cause damage to stored foods (e.g., fungi and bacteria). Usually, microorganisms 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. Fruits and vegetables are also prone to damage by microbial attack. The microbial spoilage is mainly caused by fungi, bacteria, yeast and moulds. However, a significant portion of losses of fruits and vegetables during post-harvest period is attributed to diseases caused by fungi and bacteria. The succulent nature of fruits and vegetables makes them easily invaded by these organisms [36]. However, apart from attacking fresh fruits and vegetables, these organisms also cause damage to canned and processed products. Many times, serious post-harvest diseases occur rapidly and may cause extensive break down of the commodity, sometimes spoiling the entire package [37, 38]. It is estimated that 36 % of the vegetable decay is caused by soft rot bacteria. Similarly rot in soft fruits caused by fungi is also very destructive. As far as vegetables are concerned, naturally the source of infection is from the field, water used for cleaning the surface, contact with equipment and storage environment.

The most common pathogens causing rots in vegetables and fruits are fungi such as Alternaria, Botrytis, Diplodia, Monilinia, Phomopsis, Rhizopus, Penicillium, Fusarium, etc. Among bacteria Ervinia, Pseudomonas, etc. cause extensive damage. High temperature and relative humidity support the development of postharvest decay organisms. While more acidic tissue is generally attacked by fungi, but fruits and vegetables with pH above 4.5 are mainly attacked by bacteria [39].

Waste or Loss of Food

Food Loss: Is the bigger category and incorporates any edible food that goes uneaten at any stage. In addition to food that's uneaten in homes and stores, this includes crops left in the field, food that spoils in transportation and all other food that doesn't make it to a store. Some amount of food is lost at nearly every stage of food production [40]. Food waste is a specific piece of food loss, which the US Department of Agriculture's (USDA) Economic Research Service (ERS), defines as "food discarded by retailers due to color or appearance and plate waste by consumers. Food waste: includes the half-eaten meal left on the plate at a restaurant, food scraps from preparing a meal at home and the sour milk a family pours down the drain. Losses of horticultural foodstuffs are a key problem in the post-harvest chain (Figure 2). Not only are losses clearly a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water[41].Post-harvest losses for horticultural produce are, however, difficult to measure. In some cases, everything harvested by a farmer may end up being sold to consumers. In others, losses or waste may be considerable. Occasionally, losses may be 100%, for example when there is a price collapse and it would cost the farmer more to harvest and market the produce than to plough it back into the ground. Use of average loss figures is thus often misleading. There can be losses in quality, as measured both by the price obtained and the nutritional value, as well as in quantity [42].

Fig. 2: Food Waste and Loss. Source: Rob Greenfield (2014)

Fig. 3: Mango & Tomato fruits disease (Source: unpublished. data of Ambo Post harvest research survey, 2018/19)

Post-Harvest Losses of Fruits and Vegetables Due to Disease and Insect Pests: According to Abadi *et al.* [43], 20% of fruits and vegetables losses are due to the product worsening. Vegetable and fruits crop post-harvest losses accounted to be about 30% [44] due to the presence of high moisture content (65–95%), insect infestation and damage during post-harvest handling techniques (packaging, storage and transportation). Emana and Gebremedhin [45] reported that post-harvest losses of banana was 26.5% where 56% of the loss was occurred at the marketing level due to rotting before reaching consumers in Ethiopia. While, FAO [46] reports showed that there was a greater Mango postharvest loss (35.5%) and banana (40.0%) in Jimma town and the postharvest losses were mainly attributed to poor handling during transportation and the use of poor marketing structures to sell their fruits. Also, Kasso and Bekele [47] reports the extent of post-harvest loss of horticultural crops was found higher; Mango (43.53%), Banana (20-40%), Cabbage (58.9%), Tomato (45.32%), Avocado (= 23%), Papaya (= 29.2%), Coffee (15.75%).

In general, the total postharvest loss of mango at different stages of supply chain was 35.00% in traditional method, while it was only 18.60% in improved handling practices comprising of desapping, HWT and use of MAP packaging [48]. Post-harvest decay is still a serious problem in the storage of many fresh fruits and vegetables, especially acidic, succulent and nutritious fruits and vegetables that suffer from rotting diseases. On average, 40% of fresh fruit and vegetables are lost to post-harvest disease [49] and such losses in China have been estimated as 4.5 billion US dollar per year [50].

Post-harvest loss of tomato was estimated up to 30 – 40% from harvest to market. A physiological disorder like blossom end rot and sunburn caused up to 10-18% losses (unpublished data of Ambo ARC 2018 -2019 survey) (Figure 3). Controlling or reducing disease relies on integrated crop and postharvest management, with attention to fungicide application, crop hygiene and nutrition and the management of ripening, to optimize advantages conferred by the plant's natural resistance factors that prevent and delay disease development.

Therefore, use of appropriate packaging materials, proper storage facilities and transportation can help to minimize these losses. In addition to this, modern food processing techniques and post-harvest technologies are the main tools to reduce perishable food losses and maintain the quality of products [51].

Management of Fruits and Vegetables Post-Harvest Loss: 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. Mechanical injury provides sites for pest attack and increases physiological losses. Therefore, avoid mechanical injury to the crop while handling [52]. 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.

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 [53]. 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 [54]. 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. 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. 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 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.

CONCLUSION

The production fruits and vegetables varied from cultivating of a few plants in the backyards for home consumption up to a large-scale production for domestic and export markets. Losses of fruits and vegetables are mainly caused by abiotic and biotic factors. 40-50% of horticultural crops produced in developing countries are lost before they can be consumed, mainly because of high rates of bruising, water loss and subsequent decay during postharvest handling. 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. Storing of 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. Controlling or reducing of disease relies on integrated crop and postharvest management, with attention to fungicide application, crop hygiene and nutrition and the management of ripening, to optimize advantages conferred by the plant's natural resistance factors that prevent and delay disease development. In addition to this, uses of modern food processing techniques and post-harvest technologies are the main tools to reduce perishable food losses and maintain the quality of products.

ACKNOWLEDGEMENT

The author would like thank my daughter Obse Negasa for her giving me a moral to review this paper.

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