Journal of the Saudi Society of Agricultural Sciences (2016) xxx, xxx–xxx

King Saud University
Journal of the Saudi Society of Agricultural Sciences
www.ksu.edu.sa
www.sciencedirect.com

FULL LENGTH ARTICLE

Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia

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Received 20 October 2015; revised 8 January 2016; accepted 12 January 2016

KEYWORDS

Dire Dawa;
Horticultural crops;
Post-harvest loss;
Quality deterioration

Abstract The assessment on the causes of post-harvest loss and quality deterioration of horticultural crops was carried out in Dire Dawa Administration from March 2011 to December 2012 in the eleven randomly selected representatives Peasant Associations. Stratified and multi stage random sampling techniques were used to sample representative Peasant Associations and respondents (n = 296). Both qualitative and quantitative data were gathered through questionnaire, focus group discussions, interview and observations. Data were analyzed using appropriate descriptive statistics. Climate and weather conditions, harvesting and handling techniques, packaging, storage and transportation facility, market situation, dust from cement factory, disease and pest animals were recorded as major causes for post-harvest loss. The severe post-harvest loss and quality deterioration of horticultural crops mainly occurred during harvesting followed by marketing, transporting and storage. Poor quality equipment and materials usage caused tremendous mechanical, physiological and pathological damages on horticultural crops. To minimize losses, different traditional methods were practiced by the local community. The highest post-harvest loss was recorded for tomato (45.32%) followed by mango (43.53%), whereas the least post-harvest loss was recorded for coffee (15.75%). Post-harvest loss ranging from 20% to 50% was recorded in between marketing and consumption. This can be used as a good indication as all concerned bodies should aim for development of effective and efficient policies and strategies to solve existing problems.

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Peer review under responsibility of King Saud University.

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1. Introduction

Agriculture is the mainstay of the Ethiopian economy (Bezabih and Hadera, 2007). The country has highly diversified agro-ecological conditions for the production of different cereal, legumes and horticultural crops (Bekele, 1989; Milaku, 2005). More than 85% of its population is engaged in small

http://dx.doi.org/10.1016/j.jssas.2016.01.005
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scale agricultural production as a major means of livelihood (Bekele, 1989; Fantahun and Williamson, 2001; Bezabih and Hadera, 2007). It contributes for about 50% of the country's gross domestic product (GDP), over 90% of export earnings and 73% supplies of raw materials for agro-based domestic industries (Milaku, 2005; Bezabih and Hadera, 2007).

Alazar (2007) defined horticultural crops as crops, which are not staple cereals or major industrial crops, but are mainly eaten for their contribution to the flavor and interest of food with flexible consumption based on price, quality and supply. This includes fruits, vegetables, flowers, spices, medicinal and aromatic plants and plantation crops (Choudhury, 2006).

Horticultural crop production is the major farming system in the eastern part of Ethiopia such as in Dire Dawa Administration, Fedis, Haramaya, Kombolcha, Kersa, Meta, Kurfa Chelle, Grawa, Jarso and Gemechis. Particularly in the areas where water is available and farmers have access to the market, horticultural production is used as a major source of cash income for households (Milaku, 2005; Bezabih and Hadera, 2007).

Although human and material resources are devoted for planting, irrigation, fertilizer application, 50% of horticultural crops are lost due to post-harvest loss (Saxena et al., 1990; Alazar, 2007; Olayemi et al., 2010). Post-harvest losses and quality deterioration of horticultural crops are mostly caused by pests, microbial infection, natural ripening processes and environmental conditions such as heat, drought and improper post-harvest handling (Idah et al., 2007; Olayemi et al., 2010). It occurs through all or at least one of post-harvest activities such as harvesting, handling, storing, processing, packaging, transporting and marketing (Mrema and Rolle, 2002).

Even though only limited studies were conducted in Ethiopia, post-harvest loss and quality deterioration of horticultural crops are estimated to be 25–40% (Yohannes, 1989). Particularly, in the eastern part of the country, limited post-harvest improvement studies have been carried out for locally consumed fruits and vegetables. However, fruits such as banana, orange, lemon, pineapple and avocado which exported to Arab countries, Europe and the Middle East are relatively graded and packaged appropriately (Alazar, 2007).

Reduction of post-harvest losses and quality deterioration are essential in increasing food availability from the existing production. Minimizing this loss has a great significance for food security, economic growth and welfare of the society. Therefore, this survey was conducted to assess the principal causes of post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Administration and to suggest solution to the problems.

2. Materials and methods

2.1. Study area

This study was carried out in Dire Dawa Administration located in the eastern part of Ethiopia. The region is administratively divided into nine urban and 38 rural peasant association clustered into four clusters, which covers 98.7% of the total area. According to the report of CSA (2008), the total population of the Dire Dawa Administration is estimated to be 341,834.

Dire Dawa Administration is characterized by three broad traditional Agro-ecological zones mainly based on altitude, moisture and physio-geography; namely "*Kolla*" below 1500 m asl and "*Woina Dega*" (above 1500 m asl) and "*Dega*" (above 2000 m asl). The topography of the area constitutes from very steep high mountains to flat plains, where its altitude ranges from 950 to 2260 m asl. Ecologically, the Administration covers desert and semi-desert scrub and shrubland ecosystems. It is characterized by arid and semi-arid climate with low and erratic bimodal rainfall with about 677 mm and high monthly mean maximum temperature that ranges from 28.1 °C to 34.6 °C, and monthly mean minimum temperature ranges from 14.5 °C to 21.6 °C.

Dire Dawa Administration has favorable and ideal climatic condition as most horticultural crops require high temperature. It has high potential for horticultural crops for earning cash and as source of food for most producers. Horticultural crops such as vegetables (onion, tomato, pepper and cabbages), cash crops (khat, coffee and ground nut) and fruit crops (papaya, mango, orange, mandarin, sugar apple, custard apple, date palm, banana and guava) and tuber crops (potatoes, sweet potatoes and onions) were cultivated in more than 7300 ha of land in different parts of the administration (CSA, 2008).

As Dire Dawa is one of the commercial towns of Ethiopia, the administration serves transportation of many of horticultural products such as khat, vegetables, fruits and tuber crops for domestic use and for export. It serves as a medium for export of horticultural crops to Somalia and Djibouti (Bezabih and Hadera, 2007). The Kafira market, the old and historical market, is used as a terminal market for vegetables and fruits sold by small-scale traders coming from its surroundings.

2.2. Methods

The present study was carried out from April 2012 to December 2012. Within the study sessions, the major factors for post-harvest losses and quality deterioration of horticultural crops produced were assessed in the selected representative rural peasant associations. The extents of post-harvest loss and quality deterioration were estimated from the sample analysis and respondents' estimation. The selection of representative villages and householders or respondents from each stratum was based on a multistage systematic random sampling technique. Representative villages were selected first, and then the representative habitats and respondents were selected from each village.

2.2.1. Preliminary survey

A preliminary survey was conducted during the first month of the study to identify the main rural Peasant Association that produces fruits and vegetables from irrigated fields. During this survey, all available and relevant information about the area was gathered. As producers are the main actors and risk takers for post-harvest loss and quality deterioration of horticultural crops, most of the intensive study was conducted in rural Peasant Associations. Based on the observation types of horticultural crops produced in the Administration and other relevant information, 11 Peasant Associations were randomly selected with consideration of the inclusion of different

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parts and agro-climatic zones of the Administration. The commodities that decided to be studied as horticultural crops were vegetables, fruits, tuber crops and cash crops.

2.2.2. Sampling design

A two stage random sampling technique was employed to select respondents from each of the selected Peasant Associations. At first, representative Peasant Associations were selected. Then from the selected Peasant Associations, a total of 296 representative respondents were selected based on the quota or proportionate system. In addition to producers, respondents were also purposively selected from wholesalers, retailers and consumers from Dire Dawa town and from selected representative Peasant Associations.

2.2.3. Data collection

A cross sectional type of data was collected on the principal causes of post-harvest loss and level of damage on horticultural crops with the help of pretested, structured, open and close-ended questionnaires, focus group discussion and harvesting and marketing observations and secondary data sources or document analysis.

As the result of the preliminary study indicated that rural communities participate on horticultural crop production and suffer more from post-harvest loss than urban community, more number of respondents were selected from rural Peasant Associations or from horticultural crops producers.

Primarily with the help of pretested structured open and close ended questionnaires information on types of post-harvest loss, level of post-harvest loss, mode of transport, packaging materials used, market related issues and attitude of respondents on post-harvest loss of fruits and vegetables was collected. In addition to the producers or farmers, data were also collected from wholesalers, retailers and consumers. Besides the primary data collection, guiding questions and checklist were also developed to gather general and specific information from producers, wholesalers, retailers and consumers. From focus group discussions and key informant interviews, information about the dominant horticultural crops produced in the area, agricultural practice related to post-harvest loss, means of harvesting, storage and transportation of horticultural crops, factors of post-harvest loss, and extents of post-harvest and marketing information was collected. Focus group discussions were held with community leaders, key informants, elders, youth and women farmers and responsible persons of different institutions and knowledgeable people on the subject in the study areas covering the entire selected representative Peasant Associations.

The estimation of post-harvest loss and quality deterioration on horticultural crops at different stages from production to consumption was measured by different methods such as estimating losses at producers, wholesalers, retailers and consumers level by calculating differences between fresh received and damaged products. Data were also collected on the type of items affected, the periods, stage, place and parts in which damages occurred. The post-harvest loss and quality deterioration at producer level was quantified based on the perceived estimated percentage losses and quality deterioration from the total harvested quantity. The post-harvest loss and quality deterioration of horticultural crops at collectors, wholesalers and retailers was estimated as the difference between quantity purchased and quantity sold in relation to total quantity purchased. The marketable quality of fruits was subjectively assessed following Awole et al. (2011) procedures for visual parameters of size, color, firmness, surface defects, sign of mold growth and shrinkage.

2.2.4. Data analysis

The collected data were tabulated and organized in graphs, charts and tables and analyzed using descriptive statistics using SPSS version 16.0 Statistical Software. Appropriate statistical methods such as frequency, average, standard deviation, and percentage were used. The percentage of post-harvest losses and quality deterioration at different channels of post-harvest was measured by using the modified equation suggested by Debele et al. (2007):

$$\text{Postharvest loss and quality detrioration } (\%) = \frac{W1 - W2}{W1} \times 100$$

where:

$W1$ = the original weight (kg) of given horticultural crops.
$W2$ = weight (kg) of given commodity after periodical interval of storage and transportation time appropriate to be sold or consumed.

Producers income loss due to middle men (brokers) was commuted in percentage:

$$\text{Producers income loss } (\%) = \frac{P2 - P1}{P2} \times 100$$

where:

$P1$ = price of horticulture commodity at farm gate.
$P2$ = price of horticulture commodity at final accessible market (Dire Dawa).

3. Results

3.1. Factors for post-harvest loss

As indicated in Table 1, climate and weather conditions, harvesting and handling techniques, packaging, storage and transportation and market situations were mentioned by almost equal proportion of respondents. Factors such as disease and pest animals were mentioned by relatively less number of

Table 1 Major factors for post-harvest loss.

Factors	Frequency	Percent
Climate and weather conditions	58	19.6
Harvesting and handling techniques	58	19.6
Packaging, storage and transportation facility	57	19.3
Market situation	53	17.9
Disease	37	12.5
Pests	33	11.1
Total	296	100

respondents. High temperature and low humidity and other climatic factors such as wind and flood affected the production of horticultural crops.

Post-harvest loss and quality deterioration during harvesting and handling techniques was identified by 58 (19.6%) of the respondents (Table 1). They were not aware of contamination of microorganisms and pollution with heavy metals and pesticides associated with harvesting and handling. They did not use the recommended and suitable equipment and materials for harvesting and handling. These aggravated the risks of post-harvest loss and quality deterioration of horticultural crops.

Post-harvest loss and quality deterioration of horticultural crops occurred due to lack of proper care, use of inappropriate harvesting equipment and materials and lack of motivation and interest to improve and upgrade the harvesting and handling techniques from time to time.

Problems related to packaging, storage and transportation facilities as factors for horticultural crops loss and quality deterioration were stated by 57 (19.3%) of the respondents.

Marketing situation as major cause of post-harvest loss and quality deterioration was listed by more than 17% of the respondents. The distance of the market, low price, lack of proper means of transportation and conditions of road were mentioned as discouraging factors. In addition, producing similar type of horticultural crops at the same time has affected the market value. Fungi and bacteria were mentioned as the major cause of post-harvest loss and quality deterioration by 37 (12.5%) of the respondents during marketing (Table 1).

Pest animals such as arthropod, nematodes, birds and mammals were cited by 11% of the respondents as the major causes for post-harvest loss and quality deterioration of horticultural crops. Mechanical damages such as bruising, peeling, skin breakage, egg laying and larvae development inside the tissue were ascertained as the major damages resulted from the pest animals.

Pre-harvest loss of horticultural crops in particular on fruits and vegetable was due to the environmental impact of cement factory. Although the problem was not common among the entire selected representative Peasant Associations, the impact from Pioneer Cement Factory was high in the Genda Rigie Peasant Association. Field samples taken from the farmer Yahaya Haji Wadi indicated the annual estimated production loss of 28,160 kg of mango, 500,000 kg of orange, 4000 kg of tamarind and 5000 kg of custard apple based on the average production before the damage. The areas near the cement factory face problems of waste water disposal into the farm. As the area had shortage of water, farmers irrigate their farm. Furthermore, the smoke, dust and heat released from the factory increase the temperature and cause eye burn becoming obstacle to work in the farm. Dust deposited on fruit bearing trees has highly affected harvesting of fruits.

More than 57% of the respondents harvest their crops in the morning to transport to the market for sale. Harvest of most horticultural crops was during the coolest time of the day like in the early morning or evening.

About half of respondents harvest during the coolest time of the day and about 45% of respondents prefer medium temperature for harvesting the horticultural crops. The majority (51.7%) of the respondents preferred to harvest at the time when the humidity was moderate. However, comparatively few respondents preferred to harvest at any time and at high relative humidity.

High horticultural crop post-harvest loss and quality deterioration occur during harvesting, marketing, transporting and storage. The popularly mentioned time of horticultural crops loss and quality deterioration was during harvesting followed by marketing.

Most of the materials and equipment used were poor in quality. For harvesting they use hand picking or collecting with equipment such as sickle, spade, hoe, axe, ladder locally named '*baalla*', cloth, basket, canvas, sack, plastic bucket, palm oil container, aluminum or plastic bowel, oil can and thatched and weaved baskets and containers.

The packaging materials and equipment used were mostly rudimentary type. Baskets, jute sacs, '*tubo*', wooden box, plastic crates, leaves and branches of different plants, aluminum and plastic bowel, oil can, used cloth, cloth bags and rope were the most common packing materials and equipment.

Although plastic crates were well designed to prevent physical damage and is easy to handle as packaging containers, it was not used by most respondents due to its limited distribution. It was only used for relatively delicate horticultural items. They use broken and dirty crates. To overcome the limited distribution of plastic crates, the respondents share to use it in common. Jute sacks were widely used for almost all types of horticultural crops primarily due to its least price and easy availability and strength.

Several means were used to transport the horticultural crops from farm to temporary storage or to the market. These include the human labor, donkey, mule and horse cart, camel, bajaj, minibus locally called '*Daina*', mini and Isuzu trucks. The limited availability of the means of transport, long and rough road, climatic condition of the area and the rudimentary packing materials increases the post-harvest loss and quality deterioration of the horticultural crops.

The diverse types of containers and equipment used for packaging also served as a measuring unit during marketing. Most of the measuring units or containers used were not standardized and uniform size but rather it was based on conventional type. The measuring units or containers used for marketing were wooden box, plastic crates, aluminum and plastic bowel, jute sack, '*tubo*', '*safedi*' and bundle. The measuring units were categorized according to their size, which also serve as pricing unit in the marketing of the products.

Although packing, transport and storage are known to be used to mitigate the post-harvest loss and quality deterioration by minimizing a gap between producer and consumer and between harvesting and consumption, the producers did not have suitable storage facilities and marketing sites. They lack proper marketing site in Dire Dawa town or Kafira, and forced to use the flooded area, which was filled with municipal waste and filth. In addition, their products were also exposed to direct sunlight until they were collected by the end users with a least price.

The temporary storage and warehouses constructed in different clusters and Dire Dawa Fruits and Vegetables market center buildings were not completed and started to give service. The planned buildings were not completed and fulfilled with necessary facilities. Even its construction has been interrupted.

As indicated in Table 2, the degree of the level of awareness of the respondents on the usage and practice of packaging materials were different. Although for perishable and delicate

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Table 2 Usage and practice in selection of packaging materials by the respondents.

Practices	Usages (n = 296)	
	Yes (%)	No (%)
Using non-collapsible and vented packages	55.7	44.3
Packaging containers appropriately filled	66.9	33.1
Packing materials with appropriate vapor barriers	46.6	53.4
Use of simple mechanical packing systems for volume-fill or tight-fill	72.3	27.7
Sorting and packing according to type and quality	62.2	37.8

horticultural products, the packing materials used must have property of protection of the commodity from compression, collapse and mechanical damage, about 44% of respondents did not use such materials.

Except for sensitive items such as khat, lettuce, spinach and cabbage, the majority of respondents do not use vapor barriers. However, 46.6% of the respondents used to select the packaging materials that provide appropriate vapor barrier, even though not observed using.

Simple mechanical packing systems for volume-fill or tight-fill were known to be used by more than 72% of the respondents in different containers to reduce the vibration (Table 2). However, more than 27% of the respondents did not apply and practice this method.

As observed from Table 2, more than 62% of respondents agree on the practice of the selection of packaging materials based on the type and quality of the crop. However, majority of the producers did not sort and pack their horticultural products according to type and quality of the horticultural crops.

Different major selection criteria were used by producers for the choice of packing materials. Nearly more than 41% of the respondents select the packing materials based on protection ability against temperature fluctuation, moisture loss and microorganism and other waste contamination. However, to overcome and minimize the risks associated with inappropriate packaging materials, they use the locally available plastic bags, wooden boxes with liner, metal cans and plastic cans for moisture loss sensitive horticultural crops. For items that require ventilation and air circulation, they perforate plastic bags, jute sacks or liners at regular distance to allow air circulation and prevent condensation. The rapping of horticultural crops with locally available branches, leaves, grasses, herbs and used cloths was also used for moisture retention and to reduce the possibility of cross-transfer of odors and disease.

More than 53% of the respondents protect post-harvest loss and quality deterioration of their horticultural crops by using different traditional or cultural methods. Although about 30% of the respondents use chemical or modern methods to protect post-harvest loss and quality deterioration, in reality they use it mostly during pre-harvesting agricultural operation. The rest use both traditional and chemical methods for protection.

The post-harvest loss and quality deterioration were prevented by traditional methods such as tree shade, storing in small hut or house, covering with clean straw, leaves and sorghum stalks for insulation and to avoid direct sun burn.

Another traditional method used to protect post-harvest loss and quality deterioration of horticultural crop was maintaining relative humidity by reducing temperature of the product or container or storage in order to reduce the evapotranspiration. The second technique used to maintain the relative humidity was by increasing the moisture of the air around the commodity by sprinkling, spraying and wetting the floor of store room, container or the commodity itself. In addition, vapor barrier materials such as polyethylene liner and bags and sacks, cloth coated boxes, fresh leaves and grasses and other variety of inexpensive and recyclable packaging materials were used. Despite these, wilting, shriveling, shrinking, and flaccid, decrease in weight and textural changes were commonly encountered during the study.

Curing of tuber crops such as sweet potatoes and potatoes was practiced to be stored for a length of time. They store the product at high temperature and high relative humidity in order to minimize wilting and decaying.

More than half of respondents sell their products after harvesting in the field or by taking it to accessible marketing sites with the exception of some commodities, which need to be stored to mature or for relatively less perishable products. Most of the time, resident houses were frequently used for temporary storage (43%). The use of farm field for temporary storage was practiced by a few respondents for some commodities by storing under big tree, caves or burying under the soil. The temporary storage of horticultural crops in the farm and human residence was in poor quality.

Major reasons and type of losses with their estimated post-harvest loss and quality deterioration of the commonly cultivated horticultural crops are shown in Table 3. Post-harvest

Table 3 Type and estimated post-harvest losses and quality deterioration of the dominantly cultivated horticultural crops.

Horticulture	Types of major loss	Estimated loss (%)
Tomato	Abrasion, bruise, rupture, softening, shrivel, sore, bleach, squash, crash, over ripen	45.32
Mango	Wound, scratch, rotting, bleach, squash, puncture	43.53
Potatoes	Scratch, flaccid, decay, bleach, spot, compression, wound, wilting, crush, sprouting	37.15
Orange	Abrasion, discolor, sour, decomposition, shrinkage, rough and thick peal	35.58
Mandarin	Abrasion, discolor, sour, decomposition, shrinkage, rough and thick peal	34.25
Papaya	Scratch, flaccid, decay, bleach, spot, compression, lesion, crash	30.31
Khat	Wilting, leaf shot burn, weight loss, leaf puncture	27.34
Onion	Decay, wilt, shrink, flaccid, sprouting	25.21
Guava	Skin scratch, bruising, rotting, softening, discolor	23.10
Green pepper	Flaccid, decay, wilting, color change	22.54
Banana	Decay, softening, bruising, chilling, peal split and breakage, skin graze	19.87
Coffee	Shrivel, bleach, shrunk seed	15.75

loss of 45.32% for tomatoes was recorded followed by 43.35% for mango. The least post-harvest loss was recorded for coffee. Producers in many sites revealed the occurrence of up to 100%, particularly for tomatoes and onion due to decay from lack of transportation and market.

Nearly 60% of the producers sell their horticultural crops in Dire Dawa town, whereas the rest sell on farm field to rural collectors or brokers or in the nearby towns and villages. About 42% of the respondents sell their horticultural products to the retailers or to the rural collectors who act as brokers, whereas 38.2% sell directly to wholesalers, 15.2% to consumers in the Dire Dawa town or nearby suburban or rural community consumers. Although most of the times, they tend to share with their neighbor, more than 4% of the respondents reported to sell some horticultural crops to their neighbor consumers who did not produce that particular product.

The majority of the respondents believe road and transportation had direct impact on the post-harvest loss and quality deterioration of their horticultural crops. Particularly the Kulayu and Debele Peasant Association producers, loss was more than half and in some occasion all of their produce, due to problems related to transportation and road. Although almost all peasant associations were connected by either temporary or permanent gravel or earthed road, appropriate vehicle for the transportation of their horticultural crops was lacking. Many of the vehicles used for transportation in the rural peasant associations of the Administrations were also old and not properly repaired. These problems have contributed a lot for the loss and quality deterioration of horticultural crops.

Almost half of the respondents did not carry out market assessment. They tried to sell their products randomly. However, 49% of the respondents carry out market assessment particularly for coffee and for other relatively less perishable products. They try to sell their products following the updated and appropriate price in farm gate or other market places.

Most of them believed they do not get better price for their products due to different reasons. For most horticultural crops, it was observed that producers lose more than 50% of the cost when sold at farm gate. The other reason was damage and loss of quality during transportation and other pre- and post-harvest activities.

3.2. Post-harvest loss and quality deterioration during trading and consumption

The major factors for post-harvest loss and quality deterioration of horticultural crops during marketing were due to problems related to mishandling in packaging, transportation, storage and display for sale.

Most of the packing materials and containers used were of poor quality and unfit and inappropriate for the products that lead to mechanical damages such as bruising, abrasion, sprouting, decay, chilling, rotting and softening. Tomatoes were packed in collapsible plastic containers that cause great mechanical damage. The use of public transportation for transporting passengers and commodities together, overloading and stacking and high temperature, rough road with high vibration and collision, lack of vehicle and its high cost and the use of draft animals and humans for transporting long distances in the absence of proper packing and stacking were major problems. They do no sort out ripe and unripe, ethylene producers from ethylene sensitive products, odor producers from odor sensitive products. Absence of warehouses for horticultural crops and use of human residence or working room as store were also factors for deterioration of products.

Export of horticultural crops to Djibouti and Somalia was not as such standardized. For transportation, they use none-refrigerated and none-ventilated vehicles such as ISUZU, and Rail Trucker. As a compensation mechanism of lack of refrigerated vehicles, transportation was during the night.

Most of the post-harvest loss and quality deterioration of horticultural crops at consumer level occur due to lack of proper handling and subsequent damages during harvesting and marketing process. However, damages also occur during storage, packing and transportation. Most consumers did not use proper storage for different commodities. As a result, the loss for horticultural crops was 20–50%, and for cabbage and tomatoes it was $>50\%$.

4. Discussion

The horticultural crops are inherently liable to deteriorate under different climatic and other circumstances due to their high moisture content (Kitinoja and Kader, 2002). Moreover, as they are biologically active and carry out transpiration, respiration, ripening and other biochemical activities, they tend to loss and deteriorate through time. This makes the post-harvest losses to occur in the field, packing areas, in storage, during transportation and marketing. Severe losses occur because of environmental conditions, poor facilities, lack of know-how, poor management, weak marketing processes or simply due to carelessness of farmers. Proper storage conditions, temperature and humidity are needed to lengthen the storage life and maintain quality of horticultural crops (Kitinoja and Kader, 2002). Dire Dawa Administration is characterized by high temperature combined with low relative humidity (BFED, 2010). This has a negative effect on most horticultural products as a major factor for post-harvest loss and quality deterioration.

Horticultural crops may be characterized as being either climacteric or non-climacteric, depending on their respiratory pattern. Climacteric fruits can be harvested when mature but before the onset of ripening. After the climacteric, the respiration rate slows down as the fruit ripens and develops quality (Sirivatanapa, 2006). Thus, in the present study the harvesting of mandarin without proper maturity will lead to post-harvest loss and quality deterioration.

Fresh produce needs low temperature and high relative humidity during storage and transportation (Choudhury, 2006). Therefore, reducing the temperature and increasing the relative humidity are the primary means of maintaining product quality during storage and transportation. Reduced temperature decreases the physiological, biochemical and microbiological activities, which causes quality deterioration (Thompson et al., 1998).

Horticultural crops can be contaminated with different microbial and chemical contaminants during handling and processing and become source for infectious microorganisms (Moy, 2005). Mechanical damage during harvest can become a serious problem by disposing it to decay, increasing water loss, respiration and ethylene production rates, which leads

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to deterioration (Kitinoja and Kader, 2002). Bruises and other mechanical damage affect appearance and also provide entrance to decaying organisms (Olayemi et al., 2010).

From the three cement factories operating in the Administration, the Pioneer Cement Factory was blamed to cause a great loss on the nearby horticultural crops in Genda Rigie Peasant Association. Previous studies by Asubiojo et al. (1991) and Saralabai and Vivekanandan (1992) revealed that the cement dust deposition in large quantities around cement factories causes changes on the growth and biochemical characteristics of crops and on the physical and chemical properties of the soil. The areas near the cement factory also face problems of alkalization due to high deposition of alkaline cement dust and ash. Its high dust deposition on vegetation reduces the productivity and concentration of chlorophyll (Liu et al., 1997; Raajasubramanian et al., 2011). Cement factories are sources of pollutant to surrounding areas through dust deposition that affect photosynthesis, respiration, stomata functioning and productivity. It also increases the mortality of young branches leading to a reduction in biomass and number of fruits that lead to more than half of economic yield loss (Singh and Rao, 1980; Abdel-Rahman, 2012; Abdel-Rahman and Ibrahim, 2012). The dust falling on the leaves also affects photosynthesis, stomata functioning and productivity. The impact is great around 500 m radius and slightly reduced at 5 km away from the cement factory (Abdel-Rahman and Ibrahim, 2012). Fakhry and Migahid (2011) concluded in their study that the influence of cement factories in arid regions is tremendous in vegetation diversity and the responses of individual species and the chemistry of the soil. Thus, if the current effects are not regulated, all horticultural crops and other biodiversity in the potential distance range will be vanished in the near future.

The majority of respondents seem to harvest during relatively appropriate time concerned with temperature and humidity, although night or early morning harvesting is used to lower internal temperatures and used for reduction of the energy needed for subsequent cooling (Kitinoja and Kader, 2002).

The severe horticultural crop post-harvest loss and quality deterioration were recorded mostly during harvesting followed by marketing, transporting, storage and in some cases through the entire channel. This is because fresh produce after harvest continues the process of respiration and transpiration until its reserved food and water are exhausted (Sirivatanapa, 2006). This physiological process is influenced by temperature, composition of surrounding air, and humidity of environment.

Although harvesting was carried out by hand rather than machine, some horticultural crops can be severely damaged by careless and inappropriate harvesting Absence of the use of maturity index as a standard cause high post-harvest loss and quality deterioration (Kitinoja and Kader, 2002). The containers used by pickers should be clean, smooth inside surfaces and free from rough edges (FAO, 1989). In addition, harvesting practices cause little mechanical damage by gentle digging, picking and handling (Kitinoja and Kader, 2002). Pickers should be trained to empty bags or baskets with care (Kitinoja and Kader, 2002). However, the producers throw mango, guava, mandarin, orange and papaya on to the ground from more than 3 meters high fruiting trees, that cause mechanical damages.

The use of transportation on rough road and open and closed lorry including public buses causes mechanical damage to horticultural crops as a result of vibrations and high temperature (Singh and Singh, 1992). The use of poor packaging material that restricts ventilation will also cause post-harvest loss and quality deterioration of horticultural crops (Olayemi et al., 2010).

The desired level of development in horticulture has not been achieved because of a number of constraints. Due to absence of proper storage and marketing facilities, and seasonal surplus, farmers are forced to sell their products at thrown-away prices and at the earliest opportunity after harvest (Wei et al., 2001). This also forces producers to sell their horticultural crops at very low prices for their customers. Furthermore, the lack of ability in business planning, lack of marketing knowledge and the perish ability of their products contribute to their weak influential position in the supply chain (Wei et al., 2001).

The use of chemicals must be regulated by appropriate health or food authorities. At the same time processing equipment used must be specific and standard for the treatment (McLauchlan and Bagshaw, 2001). However, in the present study rather than chemical, principally traditional techniques were more used. The treatment or the curing of root and tuber crops such as sweet potatoes and potatoes is an important practice if these crops are to be stored for long time (Kitinoja and Kader, 2002). Some plant materials are also useful as natural pesticides. For example the cassava leaves protect the harvested cassava roots from pests when used as packing material in boxes or bags during transport and short-term storage. The ashes of the leaves of *Lantana* spp. and *Ochroma logopur* have been used as a dust against aphids attacking stored potatoes. Neem leaves are also becoming more widely known and used throughout the world due to powerful pesticidal effect on food crops and non-toxicity to humans (Kitinoja and Kader, 2002).

Throughout the period between harvest and consumption, temperature control has been found to be the most important factor in maintaining product quality (Kitinoja and Kader, 2002). Keeping products at their lowest safe temperature will increase storage life by lowering respiration rate, decreasing sensitivity to ethylene gas and reducing water loss.

Exposure to the sun should be avoided as much as possible after harvest. After harvest cooling of horticultural crops is used to remove field heat. The delay in cooling will shorten post-harvest life and reduce quality. Field container should also be placed in the shade or loosely covered with leafy plant materials, straw or an inverted empty container (Kitinoja and Kader, 2002). However, repeated cooling and warming of horticultural products cause deterioration. Keeping products too cool can cause serious problem such as chilling (Shewfelt, 1986).

Although post-harvest loss estimate for horticultural crops was difficult, the current record was comparable with estimated losses recorded in Nigeria (Idah et al., 2007). Furthermore, pest, drought, shortage of fertilizer, and price of fuel for pumping water as the major constraints of horticulture production in Eastern Ethiopia were identified by Bezabih and Hadera (2007). The estimated post-harvest losses of fruits and vegetables range from 20% to 40% (Wiersinga and de

Jager, 2009). Increased returns to growers might come from proper management after harvest (Wiersinga and de Jager, 2009).

The increasing horticulture production can contribute to the commercialization of the rural economy and creates many jobs. However, expanding the scale of horticulture production is often hindered by lack of market access, market information and many biological factors (Abay, 2007). Bezabih and Hadera, (2007) also argued seasonal production to be inversely related to price.

Information on price, product demand, product supply, market place and buyers and sellers should be gathered. Although horticultural crops are exported to Djibouti and Somalia, they are not as such standardized. The logistics such as handling, packing, loading and unloading, storage, road and transportation are poor. This results in selling the Ethiopian horticultural products to conventional traditional prices (Wiersinga and de Jager, 2009).

In general, the mishandling during harvesting, packaging, transportation and storage and unfavorable climatic condition and contamination are causing mechanical, pathological and physiological damage. The support given for the improvement and reduction of post-harvest loss and quality deterioration of horticultural crops from concerned bodies is low and insufficient. Therefore urgent intervention to the existing problems is highly required. In addition, an effective and efficient intervention policies and strategies need to be developed.

Conflict of interest

Regarding the publication of this manuscript, there is no any conflict of interest.

Acknowledgments

Our appreciation goes to Dr. Fekedu Lemessa, Paulos Asrat, and Getinet Tolessa for their continuous follow-up, constructive comments, encouragements and facilitation of this study. We express our gratitude to all concerned Dire Dawa Administration officers in particular to Workineh Tilahun and Abdi Mohammed, Tesfaye Alemayehu and Ketema Zeleke to enumerators and respondents. We greatly recognize the financial, material and equipment support by Dire Dawa University and Dire Dawa Rural and Agriculture Developmental Office.

References

Abay, A., 2007. Vegetable market chain analysis in Amhara National Regional State: the case of Fogera Woreda, South Gondar Zone. M.Sc. Thesis. Haramaya University.

Abdel-Rahman, A.M., 2012. Effect of cement dust pollution on the yield and quality of *Ficus carica* L. Fruits J. Life Sci. 6, 276–282.

Abdel-Rahman, A.M., Ibrahim, M.M., 2012. Effect of cement particulates deposition on eco-physiological behaviors of Halophytes in the salt marshes of Red Sea. Am.-Euras. J. Agric. Environ. Sci. 12, 490–498.

Alazar, A., 2007. Horticultural Marketing in Ethiopia. M.Sc. Thesis. Haramaya University, Haramaya.

Asubiojo, O.I., Aina, P.O., Oluwole, A.F., 1991. Effect of cement production on the elemental composition of soil in the neighbouhood of tow cement factories. Water Air Soil Pollut. 57 (58), 819–828.

Awole, S., Woldetsadik, K., Workneh, T.S., 2011. Yield and storability of green fruits from hot pepper cultivars (*Capsicum* spp.). Afr. J. Biotechnol. 10, 12662–12670.

Bekele, W., 1989. Horticulture marketing systems in Ethiopia. First international symposium on horticultural economics in developing countries. Acta Hortic. 1, 21–31.

Bezabih, E., Hadera, G., 2007. Constraints and problems of horticulture production and marketing in Eastern Ethiopia. Dryland Coordination Report, G46, Osolo, p. 91.

Bureau of Finance and Economic Development (BFED), 2010. Dire Dawa Administration Statistical Abstract 2005/06–2008/09. BFED, Policy Study and Plan Development Co-operation Office, Dire Dawa.

Central Statistical Agency (CSA), 2008. Summery and Statistical Report of the 2007 Population and Housing Census: Population size by Age and Sex. Federal Democratic Republic of Ethiopia, Population Census Commission, Addis Ababa, Ethiopia.

Choudhury, M.L., 2006. Recent developments in reducing postharvest losses in the Asia–Pacific Region. In: Rolle, R.S. (ed.), Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region. Asian Productivity Organization, and Food and Agriculture Organization of the United Nations, Tokyo, p. 312.

Debele, D., Fekadu, L., Ravishankar, H., 2007. Development and performance evaluation of indigenously made cooling chambers for extending the shelf life of mangoes and sweet oranges. East Afr. J. Sci. 1, 127–135.

Fakhry, A.M., Migahid, M.M., 2011. Effect of cement-kiln dust pollution on the vegetation in the western Mediterranean desert of Egypt. World Acad. Sci. Eng. Technol. 57, 28–34.

Fantahun, A., Williamson, S., 2001. Ethiopian farmers test alternatives to pesticides. Pestic. News 52, 8–9.

Food and Agriculture Organization (FAO), 1989. Prevention of Post-Harvest Food Losses: Fruit, Vegetables and Root Crops; A Training Manual. UNFAO, Rome.

Idah, P.A., Ajisegiri, E.S.A., Yisa, M.O., 2007. Fruits and vegetables handling and transportation in Nigeria. Aust. J. Technol. 10, 175–183.

Kitinoja, L., Kader, A.A., 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops, fourth ed. University of California, Postharvest Technology Research and Information Center, Davis.

Liu, J.L., Du, M., Shang, K.Y., Chen, S.Y., Xu, H.B., Xie, M.Y., 1997. The effects of cement dust pollution on rice, rape and soil. J. Plant Resour. Environ. 6, 42–47.

McLauchlan, R., Bagshaw, J., 2001. Australian postharvest technologies for fresh fruits and vegetables. In: O'Hare, T., Bagshaw, J., Li, W., Johnson, G.I., (Eds.), Postharvest Handling of Fresh Vegetables. Proceedings of a Workshop Held in Beijing, People's Republic of China, 9–11 May 2001. ACIAR Proceedings No. 105.

Milaku, J., 2005. Patterns and determinants of fruit and vegetable demand in developing countries: a multi-country comparison (Ethiopia). Fruit and Vegetables for Health. Report of a Joint FAO/WHO Workshop, 1–3 September 2004, Kobe.

Moy, G., 2005. Food safety aspects in fruit and vegetables. Fruit and Vegetables for Health (FAO/WHO). Report of a Joint FAO/WHO Workshop, 1–3 September 2004, Kobe.

Mrema, C.G., Rolle, S.R., 2002. Status of the postharvest sector and its contribution to agricultural development and economic growth. In: 9th JIRCAS International Symposium – Value Addition to Agricultural Product, pp. 13–20.

Olayemi, F.F., Adegbola, J.A., Bamishaiye, E.I., Daura, A.M., 2010. Assessment of post-harvest challenges of small scale farm holders of tomatoes, bell and hot pepper in some local government areas of Kano State, Nigeria. Bayero J. Pure Appl. Sci. 3, 39–42.

Raajasubramanian, D., Sundaramoorthy, P., Baskaran, L., Sankar, K., Ganesh, A.L., Chidambaram, A., Jeganathan, M., 2011. Effect of cement dust pollution on germination and growth of groundnut (*Arachis hypogaea* L.). Int. Multidisc. Res. J. 1, 25–30.

Saralabai, V.C., Vivekanandan, M., 1992. Positive effect of cement kiln-exhaust on Legume crop under simulation study. Appl. Biochem. Biotechnol. 36, 36–46.

Saxena, K.N., Pala-Okeyo, A., Seshu-Reddy, K.V., Omolo, E.O., Ngode, L., 1990. Insect pest management and socio-economic circumstances of small-scale farmers for food crop production in western Kenya: a case study. Insect Sci. Appl. 10, 443–462.

Shewfelt, R.L., 1986. Postharvest treatment for extending shelf life of fruits and vegetables. Food Technol. 40, 7078–7089.

Singh, A., Singh, Y., 1992. Effect of vibration during transportation on the quality of tomatoes. J. Agric. Mech. Asia Afr. Latin Am. 23, 70–72.

Singh, S.N., Rao, D.N., 1980. Growth of wheat plants exposed to cement dust pollution. Water, Air Soil Pollut. 14, 241–249.

Sirivatanapa, S., 2006. Packaging and transportation of fruits and vegetables for better marketing. In: Rolle, R.S. (Ed.), Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region. Asian Productivity Organization, and Food and Agriculture Organization of the United Nations, Tokyo, p. 312.

Thompson, J.F., Mitchell, F.G., Runsey, T.R., Kasmire, R.F., Crisosto, C.H., 1998. In: Commercial Cooling of Fruits, Vegetables and Flowers, vol. 1211. DANR Publications, pp. 61–68.

Wei, S., Woods, E., Adar, D., Singgih, S., 2001. West Timor mandarin marketing case study implications for supply-chain management in developing countries. In: O'Hare, T., Bagshaw, J., Li, W., Johnson, G.I. (Eds.), Postharvest Handling of Fresh Vegetables. Proceedings of a Workshop Held in Beijing, People's Republic of China, 9–11 May 2001. ACIAR Proceedings No. 105, p. 126.

Wiersinga, R., de Jager, A., 2009. In: Business Opportunities in the Ethiopian Fruit and Vegetable Sector. Wageningen University and Research Centre – LEI, p. 46.

Yohannes, A., 1989. Economics of horticultural production in Ethiopia: first international symposium on horticultural economics in developing countries. Acta Hortic. 16, 15–19.

Please cite this article in press as: Kasso, M., Bekele, A. Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia. Journal of the Saudi Society of Agricultural Sciences (2016), http://dx.doi.org/10.1016/j.jssas.2016.01.005