International Journal of Multidisciplinary Research and Growth Evaluation.

Factors Influencing Tomato Post-harvest Losses in Mwea, Kenya

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Article Info

ISSN (online): 2582-7138
Volume: 04
Issue: 04
July-August 2023
Received: 08-05-2023;
Accepted: 28-05-2023
Page No: 41-48

Abstract
Tomato is an important vegetable crop in Kenya which is widely grown for home consumption and commercial purposes. However, the crop is faced with a number of challenges including post-harvest losses which is a major threat to harvested produce. Presence of losses in a crop indicates wastage of resources that were put in place during production. Periodic surveys are necessary to help understand the severity and causes of losses in a specific place at a specific time. The aim of this study was to survey on the severity and causes of tomato postharvest losses in Mwea, Kenya. During the survey, sixty-eight farmers were randomly selected and interviewed using structured questionnaire and factors influencing tomato postharvest losses documented. Descriptive statistics was used to analyze the information collected from the respondents. Results showed that the most common varieties grown by farmers at the time of survey were Kilele F1and Roma V.F (80.0% and 10.0% respectively). Factors influencing tomato postharvest losses were; poor means of transport (10.63%), and time lag in the market. The common pests that were found attacking tomato fruits were; American bollworms (68.5%), birds (1.2%), spider mites (19.8%), and thrips (8.1%). The most common diseases were; Fusarium rot (45.3%), Bacterial soft rot (50%), and Phoma rot (4.7%). The average losses estimated from the study was 72.0%. The study recommended that the farmers should avail themselves to seminars on fruit handling during harvesting and transport and the new tomato varieties that are resistant to pests and diseases and with good keeping quality.

DOI: https://doi.org/10.54660/.IJMRGE.2023.4.4.41-48

Keywords: Losses, Post-harvest, Tomato

1. Introduction

Tomato is an important vegetable crop in Kenya. Its production is on rise through greenhouse technology increasing hope for the supply throughout the year. The fruit is rich in calcium, phosphorus, magnesium, copper, niacin, iron, folate, Vitamin A, B6, Vitamin E, Vitamin B2, Vitamin C, iron and carbohydrates (Wamache 2005) [44]. George *et al*. (2004) [18], quoted that the fruit has lycopene, ascorbic acid and phenols which has a gentle stimulant for kidneys, washing off toxins that contaminate the body systems. The tomato fruit juice is effective in treating liver and intestinal disorders (Wamache, 2005) [44]. In Kenya tomato constitutes 7% of the total horticultural produce and 14% of the total vegetables produced (Ochilo *et al*., 2019) [34]. Tomato production averages 410,033 tonnes per year in Kenya (Ochilo *et al*., 2019) [34]. However, tomato fruits are very perishable and experience the highest post-harvest losses in the fruit and vegetable supply chains of Sub-Saharan Africa (Affognon *et al*., 2015) [2]. This is because most of the Sub-saharan African countries allocate more than 95% of their resources on production of the tomato fruits but less than 5% on maintaining shelf life of the fruits (Arah *et al*., 2016) [7]. These post-harvest losses are caused by factors such as poor production techniques, non-removal of field heat, dumping of the produce and moisture condensation causing pathogen infestation (Kader 1992) [24]. Tomato fruits have high moisture content that increases chances of post-harvest losses during transport and marketing (Sablani *et al*., 2006; Muhammad *et al*., 2011) [39, 33].

Bulk packaging without sorting and grading of produce, damage during transport and storage due to mechanical injuries are other factors that contribute to post-harvest losses (Kader, 1992; Hurst, 2010) [24, 20]. Inadequate storage, distance and time consuming market distribution, poor access to the market, post-harvest spoilage micro-organisms, cultivars disposition to diseases causes high post-harvest losses of tomatoes (Kader, 1992; Idah *et al*., 2007; Kaminski and Christiansen, 2014) [24, 21]. Rough dropping of tomato fruits during harvesting and handling causes damage that reduces shelf life of the tomato (Lee *et al*., 2007) [30]. Most of the tomato fruits are also lost after harvesting because of inadequate handling and preservation methods (Wills *et al*., 1981; Arah *et al*., 2015) [4, 45]. Fresh tomato fruit nutritional value and quality is affected by postharvest handling and storage conditions (Sablani *et al*., 2006) [39]. Tomato postharvest properties include; firmness, color, total soluble solids and shelf life (Babatola *et al*., 2008; Akter and Khan, 2011) [9, 5]. Fruits, due to their low pH, high 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; Aidoo *et al*., 2014) [32, 1]. Mycotoxins are potential health hazards to man and animals and in most cases they are unnoticed.

According to FAO (2002), records of post-harvest losses do not exist and if available they do not cover enough period of time and the figures are only estimates made by observers. It has been estimated that 20-50% of tomato fruits harvested for human consumption are lost through microbial spoilage while other losses results from damage by dynamic stresses during transit, and through rough handling during loading and offloading (Kader 1992; Okezie, 1998; Kasso and Bekele, 2016) [24, 35, 26]. Thirupathi *et al*. (2006) [43], estimated the magnitude of post-harvest losses in fresh fruits to be 25-80%. Sugri *et al*. (2013) reported that postharvest losses as high as 10-20% occur due to delays in transport arrangements and long distances to urban markets. These losses portray a wastage of scarce resources, waste of human efforts, and farm inputs (World Resource Institute, 1998).

Addressing post-harvest losses is necessary to combat hunger, improve food security and raise revenue in the country (Aulakh *et al*., 2013, Garikai, 2014; Belik, 2018) [3, 19, 13]. The extent of the losses has not been quantified in most areas and where this has been quantified, the figures vary greatly such that their usefulness is short-lived. Periodic surveys may help in understanding the severity of losses in a specific place and at a specific time. In Mwea, Kenya estimates of tomato post-harvest losses have not been established. Therefore the study aims at establishing estimates and factors contributing to tomato post-harvest losses in Mwea, Kirinyaga County, Kenya.

2. Materials and Methods

2.1 Survey Area

A survey was carried out in Mwea area of Kirinyaga County in June 2019 to determine the causes of the post-harvest losses in tomatoes in the area. The area was selected because of it being famous and has a long history of tomato production.

2.2 Sampling and Sample Size

Random sampling was used to determine the sample size of the farmers that were interviewed individually by use of structured questionnaire. A sample size of sixty eight (68) respondents made up of farmers and sellers was selected through stratified sampling and interviewed using the structured questionnaire but some were dropped from the sample size because of outliers reducing the sample size to sixty.

2.3 Data collection

Structured questionnaires were used to gather information on the factors that contribute to post-harvest losses and also physical observation of what was happening within farmers' farms. Information collected sought to understand the extent of losses, packing materials, means of transport, sorting and grading, time the crop takes in the farm before collection, pests, spoilage micro-organisms and source of labor for harvesting. Post-harvest losses were estimated by adding the average losses from the post-harvest handling processes.

2.4 Data analysis

Descriptive statistics; SPSS frequency, percent and chi-square test statistics was used to analyze the data obtained.

3. Results

3.1 Tomato Cultivars Grown in Mwea, Kirinyaga County

The tomato cultivars grown in Mwea varied significantly ($p< 0.001$) between the farmers. The most commonly grown cultivars of tomato in Mwea were: Kilele F1 Hybrid, Roma V. F. locally known as safari, Rio grande and Carl J. The largest percentage (80 %) of the farmers grew Kilele F1 while 10 % of the farmers grew Roma V. F and 3 % grew Rio grande and Carl J as shown in table 1. Only 1.7 % of the farmers grew Danish and Royal Sluice.

Table 1: Tomato cultivar grown in Mwea

Cultivar	Frequency	Percent
Kilele F1	48	80
Roma V.F	6	10.0
Rio grade	2	3.3
Carl J	2	3.3
Danish, Griffaton	1	1.7
Royal sluice	1	1.7
Total	60	100.0
p-value		<0.001

Percent values varied significantly (Chi-square test $\alpha=0.05$)

3.2 The Maturity State of Tomatoes at Harvesting Time

The survey revealed that some farmers (17 %) harvested their tomatoes when they were unripe. Others (82 %) harvested their tomatoes when they were ripe while the rest (2 %) harvested their fruits when they were over ripe especially those that were being sold locally (Table 2).

Table 2: Maturity state of tomatoes at harvesting time

State of the fruit	Frequency	Percent
Ripe	49	81.7
Unripe	10	16.7
Over ripe	1	1.7
Total	60	100.0
p-value		<0.001

Percent values varied significantly (Chi-square test $\alpha=0.05$)

3.3 Harvesting Time of Tomatoes

Harvesting time differed significantly ($p<0.001$) between the farmers. Most farmers (78 %) picked tomato fruits early in

the morning while (22 %) picked their produce in the afternoon in order to make the produce ready for collection and transportation and be available for sale in the wholesale markets the following morning (Table 3).

Table 3: Time of tomato harvesting

		Responses	
Time of Harvest		N	Percent
	Morning	50	78.1
	Afternoon	10	21.9
Total		60	100.0
p-value			<0.001

Percent values varied significantly (Chi-square test α=0.05)

3.4 Treatment of Tomato Fruits after Harvesting

The process of treating fruits after harvesting varied significantly ($p<0.001$) between the farmers. The study revealed that 92 % of the respondents do not treat their tomato fruits after harvesting. However a small percentage (8 %) treated their fruits using sodium hypochlorite after harvesting (Table 4).

Table 4 Treatment of tomatoes after harvesting

Treatment	Frequency	Percent
Yes	5	8.3
No	55	91.7
Total	60	100.0
p-value		<0.001

Percent values varied significantly (Chi-square test α=0.05)

3.5 The Source of Labor Used for Picking Tomatoes

Harvesting was done using two major sources of labour that differed significantly ($p<0.001$). Majority (88 %) of the respondents used hired labour while a smaller percentage (13 %) used family labour (Table 5).

Table 5: The source of Labor used for Picking Tomatoes

Source of labour		Responses	
		N	Percent
	Family labour	8	12.5
	Hired labour	52	87.5
Total		60	100.0
p-value			<0.001

Percent values differed significantly (Chi-square test α=0.05)

3.6 Sorting and Grading

The survey showed that all the respondents sorted their tomatoes before packing in the crates for transportation. Sorting involved only separating the diseased and healthy fruits and it was done in the presence of buyers several hours after harvesting (Fig 2). Farmers did not grade tomato fruits in terms of size, color, and firmness. Soft and overripe fruits were also mixed together.

Fig 1: Unsorted tomato fruits in a farmer's farm in Mwea.

3.7 Packing

The packing materials used by the farmers varied significantly ($p<0.001$). Most of the respondents (79 %) packed their tomatoes in wooden crates and a few in plastic crates (18 %) as shown in fig 2. The rest of the respondents (3 %) used paper cartons for packing of tomatoes (Fig 3).

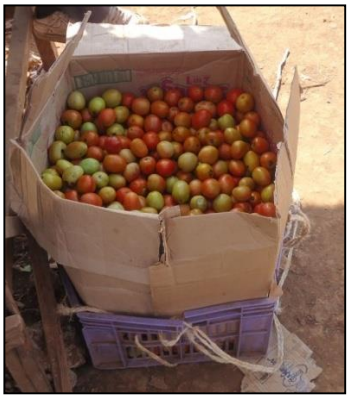

Fig 2: Tomato fruits in plastic crate lined with a paper carton in Mwea market

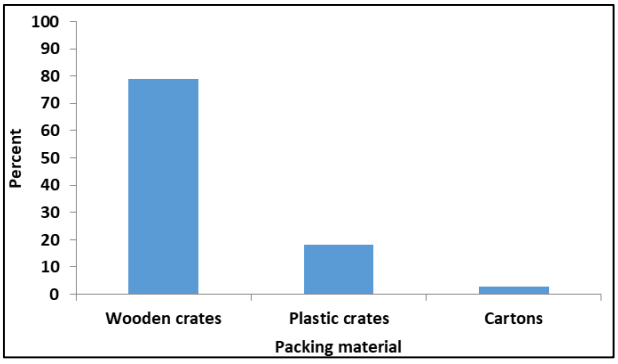

Fig 3: Tomato packing materials

3.8 Duration between Harvesting and Collection of Fruits by the Buyers

The respondents who sold their produce in wholesale to buyers from far distances like Nairobi took more than four hours before they collected them from the farm (37 %). Furthermore, 24 % of the respondents allowed the products to stay for four hours before they were collected from the farm while 21 % took three hours, 10 % took two hours, and 8 % took one hour (Table 6).

Table 6: Duration between harvesting and collection of fruits by the buyers

Time (hr)	Frequency	Percent
1	3	7.9
2	4	10.5
3	8	21.1
4	9	23.7
>4	14	36.8
Total	38	100.0
p-value		0.038

Percent values differed significantly (Chi-square test α=0.05)

3.9 Means of Transporting Tomato to the Markets

The means of transport varied significantly (p<0.001) between the respondents. Tomatoes sold to brokers were transported to the market by use of pickups (57 %) and lorries (29 %). Those who sold in the neighboring markets transported their products by motorbikes, (7 %) carts (4 %) and bicycles (1 %) (Fig.3.2). Some respondents used more than one means of transport depending on availability.

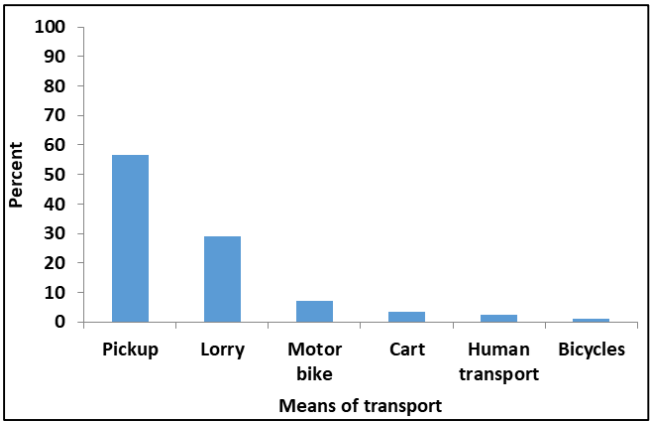

Fig 3: Means of transporting tomato to the markets

3.10 Marketing of the Produce

The marketing of the produce varied significantly (p<0.001) between the respondents. The study showed that 87 % of the farmers sold their produce in wholesale to brokers who came to buy from the farms and took them to towns like Nairobi, Embu and Nyeri. The rest (12 %) of the farmers sold in retail to the local markets like Kimbimbi and Wang'uru (Table 7).

Table 7: Marketing of the produce

Marketing		Responses	
		N	Percent
	Wholesale	58	87.9
	Retail	8	12.1
Total		66	100.0
P-value			<0.001

Percent values varied significantly (Chi-square test α=0.05)

3.11 Number of Days Taken to Sell the Tomato at the Market

The time taken to sell the produce in the market varied significantly (p<0.001) between the respondents (Table 8). The study revealed that most of the wholesalers (63 %) took less than a day to sell their produce in the market while 17 % took two days. Some farmers sold their products in wholesale in the farms. The rest (10 %) of the respondents who were also retailers took one day and three days to sell their produce.

Table 8: Time taken to sell the tomato at the market in Mwea.

Time (days)	Frequency	Percent
<1	19	63.3
1	3	10.0
2	5	16.7
3	3	10.0
Total	30	100.0
p-value		<0.001

Percent values differed significantly (Chi-square test α=0.05)

3.12 Losses due to different handling methods after harvesting

(a) Loss due to Transportation

The losses experienced by the respondents varied significantly (p<0.001) depending on the mode of transport. The study revealed that 52 % of the respondents experienced 10 % loss during transportation while 2 % experienced 30 % loss (Table 9). Other respondents did not experience losses during transportation.

Table 9: Loss due to transportation

Loss	Frequency	Percent
10%	31	51.7
30%	1	1.7
Total	32	53.3
p-value		<0.001

Percent values varied significantly (Chi-square test α=0.05)

(b) Loss due to Packing

The study revealed that 5 % of the respondents experienced 10 % loss due to packing while 37 % experienced less than 10 % loss (Table 10). The other respondents did not experience losses due to packing.

Table 10: Loss due to packing

Loss	Frequency	Percent
10%	3	5.0
< 10%	22	36.7
Total	25	41.7
p-value		<0.001

Percent values differed significantly (Chi-square test α=0.05)

(c) Loss due to Decay

The study showed that 11 % of the respondents experienced 10 % loss due to decay, while 2 % experienced 20 % and forty 40 % losses, respectively. Seven (7) % of the respondents experienced less than 10 % loss as indicated in table 11. Other respondents did not experience losses because they sold in wholesale at their farms.

Table 11: Tomato losses due to decay in Mwea

Loss	Frequency	Percent
10%	7	11.7
20%	1	1.7
< 40%	1	1.7
< 10%	4	6.7
Total	13	21.7
p-value		0.232

Percent values did not differ significantly (Chi-square test α=0.05)

(d) Loss due to Poor Grading

Poor grading resulted to fruits being rejected by the buyers and resulted to increased rot development. The study revealed that 58 % of the respondents experienced 10 % loss due to grading. Furthermore, 20 % of the respondents experienced 20 % loss during grading while 8 % of the respondents experienced 30 % loss (table 12). Moreover, 7 % of the respondents experienced less than 10 % loss while 2 % experienced more than 40 % loss during grading.

Table 12: Loss due to poor grading

Loss	Frequency	Percent
10%	35	58.3
20%	12	20.0
30%	5	8.3
< 10%	4	6.7
> 40%	1	1.7
Total	57	95.0
p-value		<0.001

Percent values differed significantly (Chi-square test α=0.05)

3.13 Common Pests Damaging Tomatoes in Mwea

About 69 % of the respondents mentioned fruit worms as the most damaging pests while 1 % birds, 20 % spider mites, 8 % thrips and 2 % whitefly as damaging pests (Table 13).

Table 13: Common pests damaging tomatoes in Mwea

Pests	Responses	
	N	Percent
American bollworm	52	68.5
Spider mites	17	19.8
Thrips	7	8.1
Whitefly	2	2.3
Birds	1	1.2
Total	79	100
p-value		<0.001

Percent values varied significantly (Chi-square test α=0.05)

3.14 Common tomato post-harvest diseases in Mwea

Diseases affecting tomato fruits in the farms varied significantly (p<0.001).The respondents (45 %) identified Fusarium rot and bacterial soft rot (50 %) as the most damaging diseases. However 5 % of the respondents indicated phoma rot as another disease that affected their tomatoes (Fig. 4).

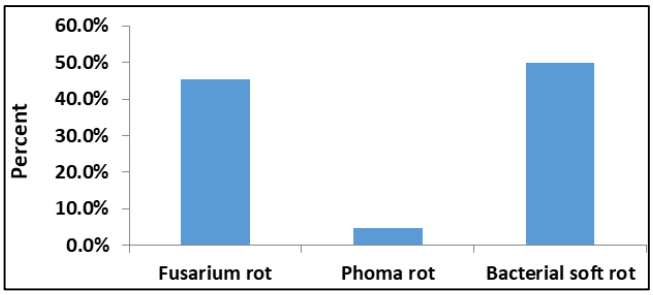

Fig 4: Common tomato diseases in Mwea

3.15 Estimation of Post-harvest Losses due to Different Post-harvest Factors

According to the study losses due to poor grading and packing averaged 10 % each, while losses due to transportation 10.63 % (Table 14). Total post-harvest losses experienced averaged 72.0 %.

Table 14: Estimation of post-harvest losses

S.No	Handling process	Average % loss
1	Sorting and Grading	22.0
2	Packing	10.0
3	Transportation	20.0
4	Decay (rots)	20.0
	Total	72.0

4. Discussion

The survey carried out revealed that factors such as poor sorting and grading, packing containers, means of transport, duration between harvest and transport to the market, pests and diseases have significant impact on post-harvest losses of tomato fruits in Mwea. During harvesting, fruits were usually thrown on the ground or dropped into the harvesting containers and the impact could cause bruises on the fruits that may act as routes for secondary infections. Other researchers such as Hurst (2010) [20], also reported that when fruits are dropped into the picking containers or any other hard surface, injuries occur which makes them to be rejected by the buyers. Tomato fruits were usually heaped on the ground awaiting for grading after harvest. Mixing of healthy and infected tomato fruits during harvesting possibly increased chances of the spread of disease causing micro-organisms to healthy fruits. It is possible that heaping of the harvested fruits on the ground during the harvesting makes the harvested fruits carry heavy spore load from the farm. Heaping of fruits in the farm also results to squeezed fruits causing injuries that allow entry of micro- organisms that cause decay.

Some harvested fruits were left lying in the farm for an average of over four hours before grading and packing. The results agree with those of Kader (1978) [28], that showed that

most of pathological disorders found during post-harvest handling of tomato fruits originate from the field and are increased by physical damage that makes the fruits more susceptible to decay. Some fruits were harvested in the morning and packed in the evening. Most of the farmers ignored treating their tomatoes with disinfectants after harvesting. This increases the chances of fruits having heavy load of disease causing micro-organisms. Similar results have been reported by other researchers such as Arah *et al*. (2016) [7], who reported that cleaning of harvested fruits is not a common practice in developing countries. Disinfectants such as sodium hypochlorite has been used to sterilize tomato fruits to reduce spore load on the fruits (Genanew, 2013) [17]. During sorting and grading the infected tomato fruits that could not be taken to the market were left in the farm. They continue to rot in the farm and may create a favourable environment for multiplication of disease causing micro-organisms.

From the survey it was also noted that the type of labor plays a vital role in the post-harvest losses. Majority of the respondents used hired labour for harvesting of tomatoes while a few used family labour. Hired labour aimed at harvesting as much fruits as possible to get a higher pay but there is poor handling of fruits resulting to bruises that increases chances of infection by pathogens that cause decay. This did not agree with the report of Ayandiji and Omidiji (2011) [8], who reported that family labour lacks skill resulting to poor handling of the fruits that results to bruised fruits. Sometimes the fruits are harvested with fruit stalks which sometimes are not removed and during packing, the stalks cause injuries on other fruits. In the research area, picking time was determined by the commitments of farmers with the buyers, for long distance transportation. It was observed that most of the farmers, who sold their produce to the local and nearby markets, picked tomato fruits early in the morning while a few of the farmers who transported their produce to distant markets picked their produce in late afternoon in order to make the produce ready for transportation overnight and be available for sale in the wholesale markets the following morning. The longer the distance from the farm to the market, the higher the chances of losses due to congestion of the tomato fruits and the resultant buildup of heat especially during the dry season (Idah *et al*., 2007; Balola *et al*., 2010; Arah *et al*., 2016) [7, 10, 21]. Tomatoes picked very early in the morning are sometimes wet due to dew or rains and when packed, the wetness encourages the multiplication and spread of decay causing micro-organisms. The dew increases moisture content that makes them more prone to fungal spoilage (Efiuvwevwere, 2000). This also corroborates with Muhammad *et al*., 2011 [33], who reported that under moist conditions, tomato fruits have a shelf life of about 48 hrs due to decay.

From the survey it was noted that majority of the respondents packed their tomatoes in wooden crates that were poorly ventilated and a few in plastic crates. A few also used paper cartons. Tomatoes are likely to suffer compression injury when piled into the transport containers. Some lined the crates with paper cartons (Plate 3.2) to prevent damage of the fruits. The crates were also covered with paper cartons on the top part especially during transportation. This increases temperature in the boxes creating a conducive environment for multiplication of pathogens. Similar results were obtained by Banjaw (2017) [11], who reported that different containers such as wooden boxes, plastic materials, sacks and baskets influence the level of produce damage. Time lag in transportation, bulky packing in the traditional wooden crates wrapped with papers may cause high humidity making the micro-climate favorable for mycoflora. Bruises and other damages on tomato fruits create an entry of decay causing pathogens (Olayemi *et al*., 2010) [36]. Overloading the transport containers creates a compression force that causes damage on tomato fruits (Hurst, 2010) [20]. Tomato fruit losses due to packing in Pakistan amounts to (23-27%) in different markets (Saeed and Khan, 2010) [40].

According to the survey carried out it was revealed that all the respondents sorted their tomatoes before packing into the crates for transportation. Sorting was done in the presence of the buyers meaning that the unsorted harvested tomatoes remained spread on the farm (Plate 3.1) for many hours making them collect very high spore load from the farm. Long contact hours of healthy and infected fruits probably increases the rate of spread of disease causing pathogens. Farmers did not grade the fruits in terms of size, color, and firmness. Mixing of small fruits with large fruits cause more bruises on the small fruits. Soft and overripe fruits were also mixed together with firm fruits making the soft ones to be compressed resulting to losses. Arah *et al*. (2016) [7] reported that sorting and grading maintains the shelf life and quality of the tomato fruits. Effect of fruit maturity on postharvest losses has been reported by various researchers. According to Arah (2015) [4], most African countries harvested tomatoes when they are partially or fully ripened and this increased chances of losses during transportation. The physiological maturity of fruits at harvest has an impact on postharvest quality of the fruits (Beckles, 2012) [12]. Reports of Toivonen (2007) [42], showed that fully ripened tomatoes are prone to mechanical injuries resulting to shorter shelf life.

The study also revealed that respondents who sold their fruits in wholesale to brokers had their products transported to the market by use of lorries and pickups from the buyers. Respondents who sold their produce to the neighbouring markets transported their products by bicycles, carts and motorbikes. Such means of transport may cause bruises on the harvested tomatoes which allow entry of pathogens that cause decay. Some fruits are also transported for longer distances to reach the market. In such cases it is possible that losses increase because of heat build- up in the packing crates and physical damage due to impact on the roads due to poor road network. Arah *et al*., 2015 [4], reported that physical damage can occur during harvesting and postharvest handling processes which include punctures, internal bruising due to impact and compression.

This study estimated the post-harvest losses to be 72.0 %. This was done by averaging losses that were reported by the respondents during the interview. The losses were attributed to poor means of transport, packaging, decay and sorting and grading. These results corroborates with Thirupathi *et al*. (2006) [43], who estimated the magnitude of post-harvest losses in fresh fruits to be 25-80%. In Rwanda, Maharashtra and Nigeria fruit losses of about 50-60% have been experienced (Kitinoja *et al*., 2019) [29]. In Nigeria post-harvest fruit losss averages between 50 and 90% (Wokoma 2008; Eni et al., 2010) [46, 15]. It was also reported that in developing countries, tomato fruit losses of up to 50% are experienced between harvesting and consumption (Kader, 2005; Pila *et al*., 2010) [23, 37]. The magnitudes of losses vary depending on distribution systems, and duration between harvest and consumption.

5. Conclusion and Recommendations

This study estimated the post-harvest losses to be 72.0 %. The losses were attributed to poor means of transport, disease causing micro-organisms, packaging and sorting and grading. The magnitudes of losses vary depending on distribution systems, and duration between harvest and consumption. This research then recommends that policy makers should encourage agro-processing industries in Mwea area to process the fruit especially the excess into other products like sauce and juice that have longer storage life. Training farmers on post-harvest handling of tomato fruits and other perishable products be provided to reduce losses. The public be enlightened on post-harvest tomato fruit decay and how it can be controlled.

6. Data Availability

Most of the data used to support the findings of this study are included in the article. Additional data are available from the corresponding author upon request.

7. Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

8. Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or non-profit sectors

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