MANAGEMENT STRATEGIES TO REDUCE POSTHARVEST LOSSES OF TOMATO (*Solanum lycopersicum* L.) IN MOROGORO, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE.
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EXTENDED ABSTRACT

Lack of simple storage facilities in tomato supply chain contributes to high postharvest losses of tomato in Tanzania. In the field, harvested tomatoes are left in an open area and occasionally covered with grasses or sometimes under shade trees. Refrigerated storage structures are relatively expensive to build and operate; and most people living in rural areas cannot afford. This study was conducted to determine the effect of on farm storage technology (zero energy cool chamber) with different harvesting stages and the transportation effect on tomato postharvest losses. Comparisons were made on deterioration of physiological weight and marketability of the fruits over time between storage in zero energy cool chamber (ZECC) and ambient conditions. Tomato harvested at mature green stage and stored under ZECC conditions exhibited significantly ($p = 0.00$) longer shelf life. Only 5% of fruits physiological weight loss was recorded in 12 days. Under ambient conditions, shelf life of tomato fruits was between 5-8 days depending on harvesting maturity stage. The loss in marketability and physiological weight exhibited similar trend. Use of wooden crates during transportation of tomato from farm to a marketplace contributed much on on-transit losses of tomato. The losses may be attributed to constant friction between tomato surface and hardened crates. The effect of lining materials in reducing these losses was assessed. The lining materials under observation included brown paper, hessian cloth and sponged paper. Wooden crates lined with hessian cloth had the lowest loss (10.6%). A significant ($p < 0.0001$) number of damaged tomato fruits were found in crates with no lining. Cost benefit analysis showed that for transport of 36 wooden crates carrying 1.44 tons of tomato, the net profit when crates are lined with hessian cloth was 118 000TZS compared to crates with no lining materials which was a loss of 12 000 TZS.

DECLARATION

I, Tumsifu Samwel, do hereby declare to the Senate of Sokoine University of Agriculture, that this Dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institutions.

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DEDICATION

This work is dedicated to my parents Mr. and Mrs. Isaac Samwel Mamboleo, my daughter Ariana Tumsifu Samwel and to all my family members.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variation
AUC	Area Under the Curve
CV	Coefficient of Variation
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
LDPE	Low Density Polyethylene
LSD	Least significance Difference
MAFS	Ministry of Agriculture Food Security and Cooperation
MUVI	Muunganisho wa Ujasiriamali Vijijini
NSPRI	Nigeria Stored Products Research Institute
PWL	Physiological Weight Loss
RCBD	Randomized Complete Block Design
SE	Standard Error
SEVIA	Seeds of Expertise for Vegetable Sector of Africa
SIDO	Small Industries Development Organization
ZECC	Zero Energy Cool Chambers

CHAPTER ONE

1.0 GENERAL INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the edible, often red berry-type fruit which belongs to the night shade family, Solanaceae. The species originated in Central and South America. In Tanzania, tomato is the most important vegetable crop representing 51% of total vegetables production (MAFS, 2012). Its production is widespread in the country with a total annual production of more than 255 000 tons (FAO, 2012). The leading producing areas in the country are Iringa (4248 ha), Tanga (1289 ha), Morogoro (1062 ha), Kilimanjaro (900 ha), Mbeya (380 ha) and Dar es Salaam (353 ha), Dodoma, Mwanza and Arusha (MAFS, 2002).

The peak season for production of tomato starts from July to November and offseason starts from February to June. Tomato is among the most perishable vegetable crops with significantly high postharvest losses. Vegetables including tomato are harvested when they are fresh and are inherently with high moisture content. The high moisture content makes their handling, transportation and marketing a challenge particularly in the tropics (Sablani *et al.*, 2006). In developing countries, where transport infrastructure and storage facilities are poor, the losses of fresh produce vary between 25-50% of the total production (Karki, 2005). Postharvest losses of tomato occur at any point along value chain between harvest and up to consumption.

Tomato is one of the most widely grown vegetables in Morogoro region. Tomato production is an important economic activity in the region which generates income to small holder farmers. Its production ranges from 2.2- 16.5 tons/ha (Maerere *et al.*, 2006). After harvest, most farmers pack tomato in wooden crates or bamboo woven baskets either without lining, lined with grasses or banana leaves. Tomatoes are transported using non-refrigerated trucks which expose them to heat and rain. This increases quality deterioration and reduction of the volume finally sold. At the same time, the use of grasses and banana leaves as lining materials is prohibited in major markets in the country. The study conducted by MUVI-SIDO (2009) reported that poor packaging materials lead to losses of up to 40%. Poor transportation and packaging can lead to 30-40% postharvest losses (AVRDC, 2014). Physical injuries, high storage temperature, high moisture content and ethylene production have been cited to limit storage life of tomato (Mutari and Debbie, 2011). There is a need to assess the effect of different lining materials as one way of reducing losses on transit.

Lack of storage facilities from the fields to the market also contribute much on postharvest losses of tomato. In the fields, harvested tomatoes are left on an open area occasionally covered with grasses and sometimes under shade trees. Most farmers sell their tomato at the farm gate. If not sold in time, the farmer is forced to sell the produce at very low price to avoid loss. The study conducted by MAFS (2002) found out that none of the surveyed smallholder farmers, individual sellers or middlemen in the domestic market had storage facilities for their produce. The facts above suggest the need of introducing affordable on-farm storage technologies to reduce on-farm postharvest losses. Zero energy cool chambers are an on-farm low cost cooling technology which does not require electricity or power to operate. The materials required are bricks, sand and water which are locally available and at affordable price. Cool chambers can reduce temperature by 10-15^{o}C and maintain high humidity of about 95%. This can significantly maintain quality and improve shelf life of tomato (Roy and Pal, 1989).

1.1 Objectives

1.1.1 Overall objective

To reduce on-farm and on-transit postharvest losses of tomato in Morogoro region through improvement of available postharvest technologies.

1.1.2 Specific objectives

i. To assess the effect of zero energy cool chamber on on-farm tomato postharvest loss reduction.

ii. To evaluate the effect of different lining materials on in-transit tomato loss reduction.

1.2 Description of the Study Area

The experiment was conducted in three villages: Mlali (06^{0}57” S 37^{0}32” E), Kipera (06^0 56” S 37^{0}32” E) and Mkuyuni (06^{0}38” S 37^{0}31” E), Morogoro region, during the period of April-May (wet season) and September-0ctober (dry season) 2017. The region has average temperature of 24.6^{0}C and 935 mm of rainfall per year. The area is classified under tropical-climate.

1.3 Literature Review

1.3.1 Effect of storage conditions on quality and shelf life

Studies show that most fruit vegetables can naturally maintain premium quality for only 2-4 days, but can be extended to 8-15 days if efficient storage facilities are available (Achoja and Okoh, 2013). According to the study done by Jany *et al.*, (2008) quality of vegetables stored under freezing conditions remained better after 3 months of storage and that the shelf life of stored vegetables was comparatively better. Tomato stored in polythene bags remained marketable for up to 10 days of storage. Tomatoes were in red colour, firm and the physical appearance was comparatively better. However, after 9 days, the tomato started shrinking and become un-marketable after 12 days of storage.

The postharvest quality and shelf life of fruit vegetables is affected by varietal characteristics, harvesting stage and storage duration. Telmo-Red sweet pepper variety harvested at 25% and 50% ripening stages and stored under passive refrigeration system maintained better postharvest quality and extended their shelf life for more than one month (Tsegay *et al.,* 2013). Cauliflower stored in perforated polythene bag can prolong shelf life and help maintaining physical appearance, acceptability and economic return (Talukder *et al*., 2002). The study done by (Babatola *et al*., 2008) showed that deep freezer storage condition ranked best (at 5% level of significance) in terms of quality preservation of tomato among all other treatment combinations. Deep freezer-DF (0°C; 95% RH), Ambient storage environment-ASE (32°C; 85% RH) (as control), Room refrigerator-RR (12°C; 85% RH), Storage Incubator-SI (8°C; 80% RH), four tomato varieties: NH84/TIL, NH84/TSLN, NH84/TBLN; NH84/TSN) were used. The results revealed that combination of tomato variety NH84/TSN with deep freezer condition gave best result in this study.

1.3.2 The effect of harvesting stages and storage conditions on the nutritional value of Tomato

Maturity stage has an influence on the weight loss, shelf life and non-reducing sugar (Hossain *et al.,* 1996). The half ripen tomato was found to have has given the best result in the vitamin C (12.21 mg/100g) and titrable acidity (0.463%) values. According to the study by Moneruzzaman *et al*. (2009) showed that the vitamin C and titrable acidity content of tomato juice increased with maturity stages and reached a peak and thereafter decrease. It was found that pH value increased with the advancement of fruit ripening. The highest pH value was observed in mature green tomato followed by half ripe and full ripen tomato. The other factors such as total sugar and Total Soluble Solids were increased with the advancement of fruit ripening, irrespective to maturity condition. Tsuda *et al*. (1999) stated that total sugar and TSS content of Mango fruits increased during the ripening period and storage. The increased in total sugar content might be due to conversion of starch into sugars. Shelf life of tomato is influenced by combined effects of stages of maturity storage conditions and time. Percentage of vitamin C and non-reducing sugar decreased as a time of storage increased (Mallic *et al*., 1996). The storage conditions also showed significant influence on different parameters studied. The combined effect of maturity and storage conditions have also significantly influence on physico-chemical characters of tomato during ripening. The full ripen tomato placed over Calcium Carbide (CaC^{2+}) and covered with polythene showed highest decay or rotting, titrable acidity, reducing sugar, non-reducing sugar and total sugar at the final day of observation (Winsor *et al*., 1962). The mature green tomatoes kept in uncovered condition showed the lowest in decay or rotting, vitamin C, titrable acidity, sugar reduction, non-reducing sugar and total sugar (Mallic *et al*., 1996).

Anju-Kumari *et al.* (1993) reported that the shelf life of tomato cultivars were longest when harvested at green mature stage. The fruit acid content is lower in immature fruit and highest when the color starts to appear, with a rapid decrease when the fruit ripens. Concentration of acid linearly reduced when temperature increased and then went up again when fruit stored at 15°C (Islam *et al.*, 1996). pH is an important factor in fruit processing industry. Cultivars with high pH are not suitable for processing. Saimbhi *et al*. (1987) reported a wide range of variation of pH content from 3.6 to 4.6 in different tomato varieties. Botrel *et al.* (1993) observed that ripen pineapple fruits held at 5°C had higher pH than 25°C.

1.3.3 Relationship between packaging materials and postharvest losses of tomato

In Tanzania, tomatoes are usually packed tightly in poor quality; traditional standard wooden crates (around 40 kg/crate) and the fruits are squashed, crushed, rubbed or damaged by the rough wooden surface. This is the usual situation at the Kilombero wholesale and retail market after tomatoes were transported from farm gate to the markets in Arusha, a city in northern Tanzania. Such poor transportation and packaging result in 30-40% postharvest losses (AVRDC, 2014). To minimize postharvest losses during handling and transportation of vegetables, selection of suitable packaging material is central. Usually, losses occur from poor storage conditions in the markets and poor packaging during transportation (Mbuk *et al.*, 2011). There are several types of packaging materials which are used to transport tomato, for example, wax coated fiber box, wooden crates, traditional boxes, nestable plastic crates and steel collapsible crates. Though there are several packaging containers used for packing fresh produce for long distance transportation, it was observed from the study by (Idah *et al.*, 2007) that baskets, jute bags/sacks are the most common transport containers used in Nigeria. The palm leaf-woven baskets were used for transporting tomato for long distances while in some cases they were used to package and transport okra for short distances. Oranges, onions and pepper are usually transported using the jute sacks or woven bags made from polypropylene. In Ethiopia, the packaging materials and equipment used are mostly rudimentary type. Baskets, jute sacs, wooden box, plastic crates, leaves and branches of different plants, aluminum and plastic bowels, cloth bags and rope are the most common packing materials and equipment in the country (Kasso and Bekele, 2015).

Jayathunge *et al.* (2009) reported that among rigid containers evaluated such as nestable plastic crate, collapsible plastic crate, collapsible steel crate, wooden box, fiberboard box and wax coated fiberboard box, the nestable plastic crate was the most suitable package type for handling and transporting vegetables, both in terms of technical and economic feasibility. Also among all these types of packaging materials, studies show that traditional boxes have highest postharvest losses than other types.

1.3.4 Effect of zero energy cool chambers on shelf life and post-harvest quality

The storage of fruits in zero energy cool chambers (ZECC) enhanced their shelf life by reducing transpiration and respiration rates (Dhemre and Wasker, 2003). The ZECC enhance shelf-life of fruits by lowering temperature and maintaining high humidity inside the chamber (Roy and Khurdiya, 1983). On farm storage plays a vital role in maintaining quality soon after harvest. An experiment conducted by Singh *et al.* (2010) to evaluate the efficacy of ZECC along with some post-harvest treatments on storability and fruit quality attributes of berry cv. ‘Gola indicated that ZECC gave 7 days of shelf life extension and concluded that it may serve as an ideal on-farm storage facility for maintaining quality of berry fruits under semi-arid environment.

Higher humidity and lower temperature inside the ZECC offers a unique advantage for maintaining the firmness of fruits and vegetables by lowering the physiological loss in weight (PLW) and other metabolic processes. According to the study done by (Sunita and Dilip, 2018) revealed that leafy vegetables, tomatoes and brinjals and cauliflowers had a shelf life of ½, 1, 1and 1 days at room temperature respectively as compared to 5, 6, 5 and 6 days in summer season when stored in the ZECC but in stored in winter season generally leafy vegetables, tomato and brinjal and cauliflower had a shelf life of 1, 3, 2 and 2 days at room temperature, respectively, as compared to 10, 12, 11 and 12 days when stored in the ZECC.

Based on the findings of the study by (Aromiwura, 2016), it was concluded that tomato marketers were not aware of the different types of zero energy cooling chambers. This implies that they were not aware of the effectiveness of the facilities. This low level of awareness could be as a result of the poor extension system of tomato post-harvest practices in the country. Upon completing the study, it was also concluded that tomato marketers adjudged the ZECC as effective for maintaining fruit firmness and fruit colour overtime, ability to extend shelf life and reduce disease incidence, maintenance of acceptable tomato fruit quality for marketers and consumer. Based on the findings of the study, the following recommendations were therefore suggested that steps should be taken towards creating a nationwide awareness about the zero energy cooling chambers and improved post-harvest packaging facilities especially to areas where tomato are produced and marketed. Awareness about the ability to extend shelf life as well as still maintains quality over the local method should also be created among tomato value chain community as well as the consumers. This will help in creating an enabling environment for marketing tomato handled and stored using these improved facilities.

1.3.5 Evaporative cooling storage

Cooling through evaporation is an ancient an effective method of lowering temperature. When water evaporates, it draws energy from its surroundings which produce a considerable cooling effect. In the evaporative cooled storage chamber, air temperature is decreased from 36 to 16.4°C, while relative humidity is increased from 25.4 to 91.1%, which is appropriate for reducing postharvest losses of fruits and vegetables due to physiological weight loss (Hirut *et al.*, 2004).

The principle of evaporative cooling depends on cooling by evaporation. As water evaporates it has a considerable cooling effect and faster the rate of evaporation.

Evaporative cooling occurs when air, which is not already saturated with water, passes over a wet surface. Water evaporates into air raising its humidity and same time cooling the bed. Efficiency of evaporative cooler depends on humidity of the surrounding air. Very dry, low humidity air can absorb a lot of moisture so considerable cooling occurs. In extreme case of air that is saturated no evaporation can take place and no cooling occurs. During the evaporative cooling, in theory the lowest temperature that can be reached is wet bulb temperature (Seyoum and Woldetsadik, 2004).

Relative humidity, air temperature, air movement, and surface area are the four major factors that impact the rate of evaporation. It is important to keep in mind that they usually interact with each other to influence the overall rate of evaporation, and the rate and event of cooling. Different types of evaporative cooler have been reported in the literature, some of which include pot-in-pot, cabinet cooler, charcoal cooler, and static cooling chamber.

(a) Passive /Desert cooler

Passive cooler (also swamp cooler, desert cooler and wet air cooler) is a device that cools air through the evaporation of water. Evaporative cooling differs from typical air conditioning systems which use vapor compression or absorption refrigeration cycles. Evaporative cooling works by employing water's large enthalpy of vaporization. The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation), which can cool air using much less energy than refrigeration. In extremely dry climates, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants. Unlike closed-cycle refrigeration, evaporative cooling requires a water source, and must continuously consume water to operate (Helsen and Willmot, 1991).

Low temperature and high relative humidity can be achieved by using less expensive methods of evaporative cooling (Seyoum and Woldetsadik, 2004). Evaporative cooling has been reported for achieving a favorable environment in greenhouses (Jain and Tiwari, 2002), animations and the storage structure for fruit and vegetables (Umbarker *et al*., 1991).

(b) Pot in pot cooling (Zeer Storage)

The Nigerian Stored Products Research Institute (NSPRI) developed some passive evaporative cooling system. One such system is the pot-in-pot method. It consists of a burnt clay plot of about 65 cm height and a wall thickness of about 8 mm. The small pot was placed inside another slightly bigger pot leaving a space of about 7 cm all around. The space between the pots was filled with sand and the sand was kept moist by watering frequently. The clay pot was provided with a suitable lid (NSPRI, 1990).

The pot-in-pot cooler works on the principle of cooling resulting from the evaporation of water from the surface of the structures. The cooling achieved from this device also results in the high relative humidity of the air in the chamber from which the evaporation takes place relative to the ambient air.

Mohammed Bah Abba is from northern Nigeria who won the 2001 Rolex Awards Enterprise for his invention of a simple cooling system that can help preserve food in rural areas where there is no electricity (NSPRI, 1990). The evaporative cooler works on the principle of cooling resulting from the evaporation of water from the surface of the structures. The cooling achieved from this device also results in the high relative humidity of the air in the chamber from which the evaporation takes place relative to the ambient air.

During the pot-in-pot storage, eggplants stayed fresh for 27 days, instead of the usual three. Tomato and peppers last fresh for up to three weeks (NSPRI, 1990). According to the study conducted by Peter *et al*. (2010) it was concluded that pot in pot storage is the best storage methods for small scale farmers who cannot afford to buy the modern cold storages. The result on the study showed that, even if some tomato and orange quality parameters decreased with the storage period the products stored in the pot-in-pot technology were better than the one from the control.

(c) Charcoal cooler

Cooling is a process used to extend shelf-life of agricultural produce through slowing down of the respiration rate. The process is accompanied by an increase in the humidity within the storage room which minimizes moisture loss from the fresh produce (Wills *et al.*, 2007). The stored produce hence takes a considerably longer time to deteriorate or undergo structural decay because of a reduced risk of microbial growth facilitated by lower temperatures and a higher relative humidity within the cold storage facility (Wills and Golding, 2016). Evaporative cooling is an innovative and environmental friendly air conditioning system that operates using induced processes of heat and mass transfer where water and air are working fluids (Camargo, 2007; Abdul-Rahman *et al.,* 2015; Omodara *et al*., 2016). Such a system provides an inexpensive, energy-efficient, environmentally benign (not requiring ozone-damaging gas as in active systems) and potentially attractive cooling system (Zahra and John, 1996).

Evaporative charcoal coolers are used for all types of agricultural produce especially tropical fruits and vegetables. The charcoal-laden walls of the cooler provide an environment which is both lower than ambient temperature and at a higher level of relative humidity for storage of fresh agricultural produce.

Erick *et al*. (2018) conducted a study aimed at evaluating the technical performance of an evaporative charcoal cooler and its effects on the quality of amaranth and spinach. The cooler microclimate and ambient conditions were investigated by measuring air temperature and relative humidity. The maximum cooling potential for the cooler was found to be 16.85°C while the maximum relative humidity difference between the cooler and outdoor conditions was found to be 38.07%. The charcoal cooler attained the highest relative humidity and the lowest temperatures. The analysis indicated that vitamin C, colour and weight of spinach and amaranth reduced with storage time. Based on a usable limit of 70% loss in moisture content, the shelf-life of amaranth was increased from two days in the control environment (outdoors) to seven days in the cooler, while that of spinach increased from three days to nine days. Overall, the charcoal cooler is beneficial in extending the shelf-life of leafy vegetables and preserving their quality.

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CHAPTER TWO

2.0 THE EFFECT OF ZERO ENERGY COOL CHAMBERS ON ON-FARM TOMATO POST-HARVEST LOSS REDUCTION

2.1 Abstract

The study was conducted to investigate the effects of zero energy cooling chambers (ZECC) and harvesting maturity stages on increasing shelf life of tomato fruits. In the wet season, the interaction between storage conditions, time and harvesting maturity stage was not significant ($p \leq 0.05$). In dry season, the physiological weight loss with respect to storage conditions, harvesting maturity stage and storage time was highly significant ($p < 0.0001$). Physiological weight loss was significantly higher in ambient storage ($p = 0.007$) compared to storage under ZECC conditions. In the wet season, storage under ZECC conditions led to significantly ($p < 0.0001$) higher marketable fruits compared to ambient conditions. The study demonstrated prolonged shelf life of fruits harvested at mature green stage and stored under ZECC conditions.

2.2 Introduction

Tomato (*Solanum lycopersicum* L.) belongs to the family *Solanaceae,* and is the most widely grown fruit in the world being recognized as widely consumed, nutritious, and perishable. It is among the most economically important vegetable next to potatoes worldwide (Nasrin *et al.*, 2008; Bergougnoux, 2014). Tomato production accounts for about 4.8 million hectares of harvested land area globally with an estimated production of 162 million tons (FAOSTAT, 2014). In Tanzania, it is widely accepted and commonly used in a variety of dishes as raw, cooked or processed product more than any other vegetable. Moreover, it is a cash generating crop to small holder farmers and provides employment in the production and processing industries. Farmers are interested in tomato production than other vegetables for its multiple harvests, high profitability and its potential to improve income and nutrition of household (Lemma, 2003). Lack of storage facilities from the fields to the market contributes much on post-harvest losses of tomato. In the fields, harvested tomatoes are left on an open area occasionally covered with grasses and sometimes under tree shades. This study has been conducted to determine the effect zero energy cooling chamber on on-farm post-harvest losses reduction.

2.3 Materials and Methods

Three zero energy cool chambers were constructed at Mlali, Kipera and Mkuyuni villages. The villages were selected based on their high potential in production of tomato in the region. The ZECC was constructed with double walls, the inner brick walls been length 165 cm × width 115 cm × height 67.5 cm (1.28 m^3) which can hold 12 crates. Ten centimeters gap was left between the outer and inner wall and filled with sand. Forty liters of tap water was applied to the sand through using watering can to make sure the sand was wet all the times. A drip line connected to a 20 L bucket was used to maintain moisture of the sand throughout gravity. Throughout a period of 20 days a total of 400 liters of water were used in this way. Palm leaves lined with sisal woven sheet were used to make top lid of the chamber. The sisal woven sheet was kept wet all the time by deeping the sheet in the water before covering the chamber cap to improve cooling effect of the ZECC. Tomato cv. Asila was used in this experiment. Fruits were harvested at three maturity stages as suggested by USDA colour chart (USDA, 1975): mature green, breaker and mature red. Fruits were filled in six plastic crates per treatment (approximately 45 kg each) as per storage condition. Tomato fruits free from defects, with uniform shape and size were sorted and used in this experiment. Fruits of each maturity stage were washed, air-dried and packed in wooden crates. The five hundred fruits were selected fruits weighed, labeled and then randomly put in ZECC and ambient storage conditions for evaluation.

2.4 Experimental Design

Field experiments laid in split plot design with three replications were conducted in the villages of Mkuyuni, Mlali and Kipera, Morogoro separately in two seasons (wet and dry seasons). Treatments comprised of two factors: two storage conditions (ZECC and ambient) and three harvesting maturity stages (mature green, mature red and breaker). Storage conditions were main factors while harvesting maturity stages were sub-factors.

2.5 Data Collection

2.5.1 Determination of physiological loss in weight

Physiological weight loss (PWL) was the one of main factors in determining the quality of stored fruits. The readings were made at one-day intervals during the experiment period. The shelf life of fruits and vegetables was determined on the basis of five percent PWL on which tomato fruits results in a loss of freshness and wilting appearance. The stored tomato was evaluated daily by using Canadian Hydrographic service hanging weighing scales (1 X 110 Kitchen Dial Scale by Pit Bull). Physiological weight loss was calculated by using the following formula;

Physiological weight loss = $\frac{X1-X}{X1}\ X100$……………………………………..(1)

Where *X1*= Initial weight, *X*= Weight at the end of storage time

2.5.2 Relative humidity and temperature

The storage air temperature and relative humidity of the zero energy cooling chamber and ambient condition were measured daily throughout the storage period. The temperature and relative humidity of storage conditions were measured using digital humidity/ temperature meter at six hours' intervals during the day. The measurements were taken at 6:00 am, 12:00 noon and 6:00 pm. For ZECC the instrument was placed at the middle of the chamber.

2.5.3 Percentage marketability

The percent marketability was assessed according to Mohammed *et al.* (1999) at an interval of two days. These descriptive quality attributes were determined subjectively by observing the level of visible defects beyond the level acceptable at the local market. The percentage of marketable fruits during storage was calculated as follows.

Marketable tomato fruits (%) $= \frac{\boldsymbol{Number\ of\ marketable\ tomato\ fruits}}{\boldsymbol{Total\ number\ of\ tomato\ fruits}} \times \mathbf{100}$………..(2)

2.6 Data Analysis

Data on physiological weight loss and marketability of fruits stored at different storage conditions were analyzed using R software. A time curve plot was drawn to depict the trends in marketability and physiological weight loss over time. The areas under the curves (AUCs) were computed using the trapezoidal sum rule in order to determine the speed of increase in PWL and loss of marketability (1/AUC). The AUCs were subjected to a one-way ANOVA to determine the significance of variation of increase in PWL and drop of marketability between storage conditions. Since the experiment was conducted in two seasons dry season and wet season, in order to the difference in seasons each season was analyzed separately.

The shelf life was determined by identifying the number of days it takes to reach 5% of physiological loss of weight. Analysis of variance (ANOVA) was performed and when significant differences existed ($p < 0.05$), the Least Significant Difference (LSD; $\alpha = 0.05$) test was used as a means separation procedure.

2.7 Results

2.7.1 Physiological weight loss

It was found that the storage conditions had significant effect on fruit physiological weight loss. Storage in ambient conditions led to significantly higher ($p = 0.0002$) physiological loss of weight compared to tomato fruits stored under ZECC. There was also significant ($p = 0.027$) variation in the rate of physiological weight loss in different storage conditions (Fig. 2.1). The rate of physiological loss of weight was significantly higher in ambient conditions compared to fruits stored under ZECC conditions (Fig. 2.2). The interaction between storage conditions, time and maturity stage in the wet season was not significant ($p \leq 0.05$).

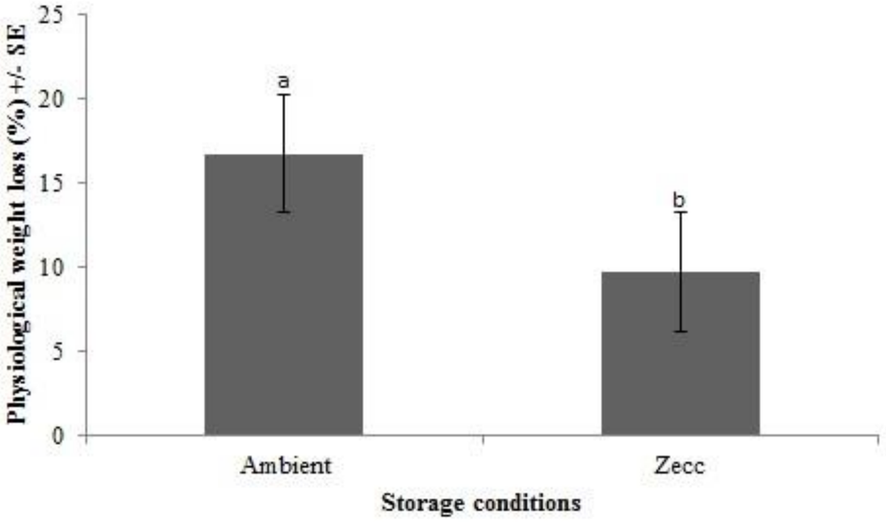

Figure 2.1: Mean physiological loss of weight in different storage conditions in wet season. Bars with different letters represent means that are significantly different at P<0.05 by Fishers' LSD. ZECC = zero energy cool chambers.

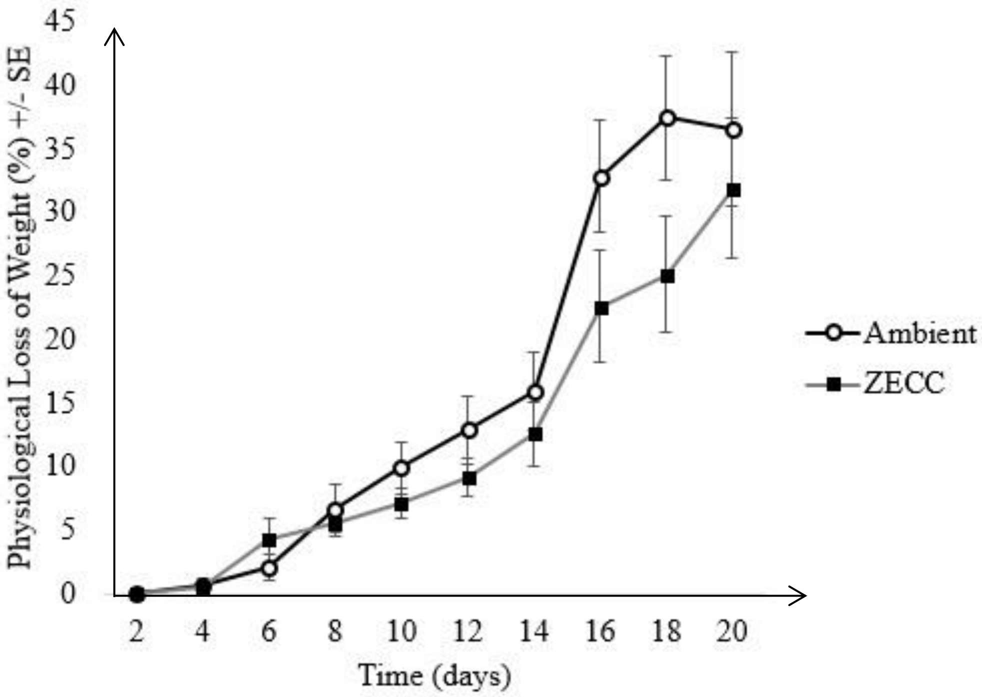

Figure 2.2: Progression of physiological loss of weight of tomato in different postharvest storage conditions in wet season. ZECC = zero energy cool chambers.

In dry season, the PLW with respect to storage conditions, maturity stage and harvesting time was highly significant ($p< 0.0001$). The rate of loss of physiological weight was significantly ($p= 0.007$) higher in ambient storage compared to the ZECC storage conditions (Fig. 2.3 and Fig. 2.4). The variation in the three-way interaction term of the three parameters was also highly significant ($p= 0.002$). The difference in fruit physiological weight loss with respect to seasons was not significant ($p \leq 0.05$).

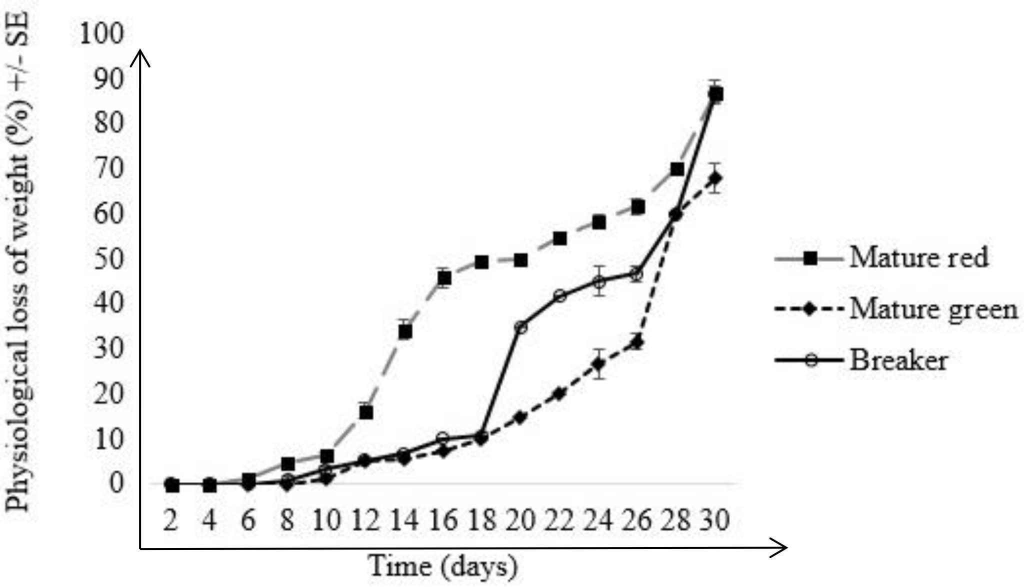

Figure 2.3: The effects of ambient storage conditions on physiological weight loss of tomato fruits harvested at different maturity stages during the dry season.

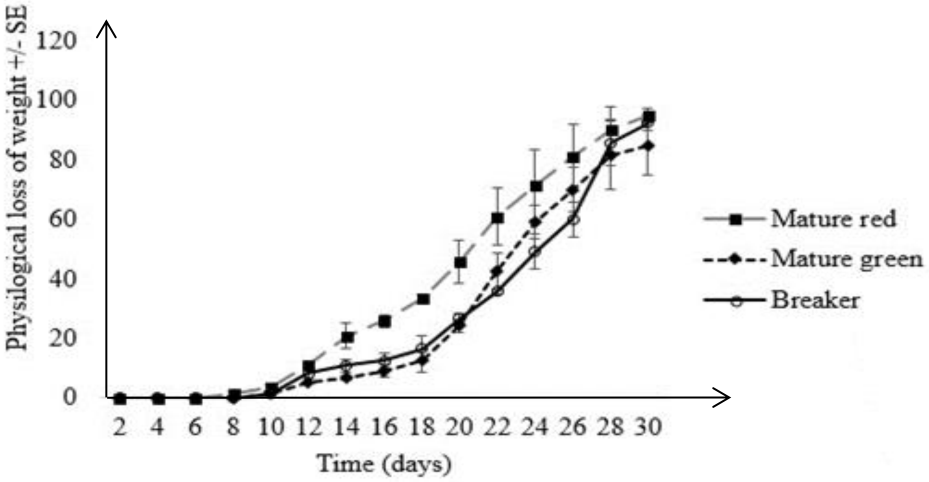

Figure 2.4: The effects of ZECC storage conditions on physiological weight loss of tomato fruits harvested at different maturity stages during the dry season. ZECC = zero energy cool chambers.

A decrease of only 5% in PWL often results in a loss of freshness and a wilted appearance (Parvez and Tutseo, 2012). The shelf life of tomato fruits harvested at mature green stage and stored under ZECC conditions was 12 days which was significantly higher ($p = 0.004$) than fruits stored under ambient conditions (Fig. 2.5).

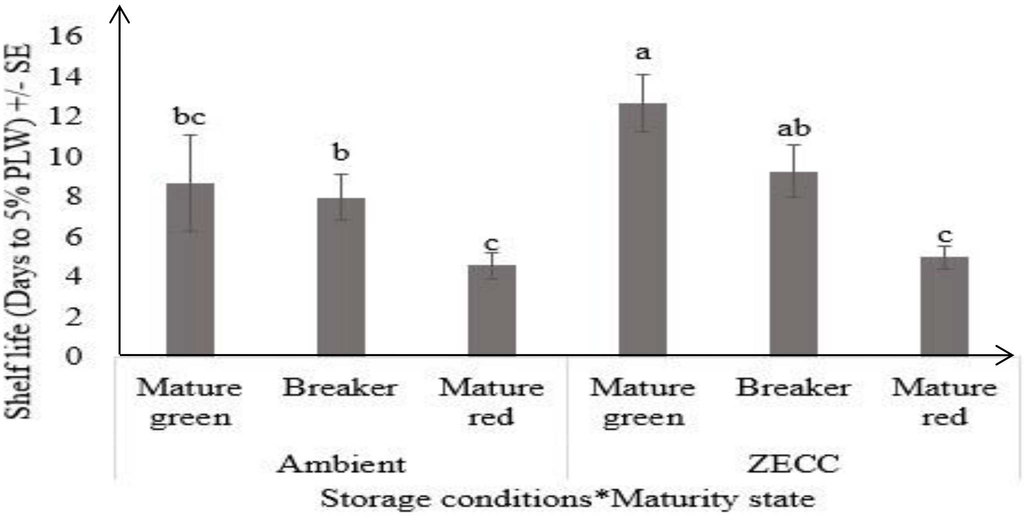

Figure 2.5: Shelf of tomato fruits in different harvest maturity stages stored under different conditions. Bars with different letters as data labels represent means which are significantly different as per Fishers' pairwise comparison method (P<0.01). ZECC = zero energy cool chambers.

2.7.2 Temperature and relative humidity

The ambient dry bulb air temperature of the experimental area varied from 23.4°C to 36.7°C and humidity was between 45% to 66%. In the zero energy cooling chambers, the dry bulb temperature and relative humidity varied from 18.5°C to 24.5°C and 88% to 80 %, respectively, during the storage period of May–June (Fig. 2.6 and 2.7).

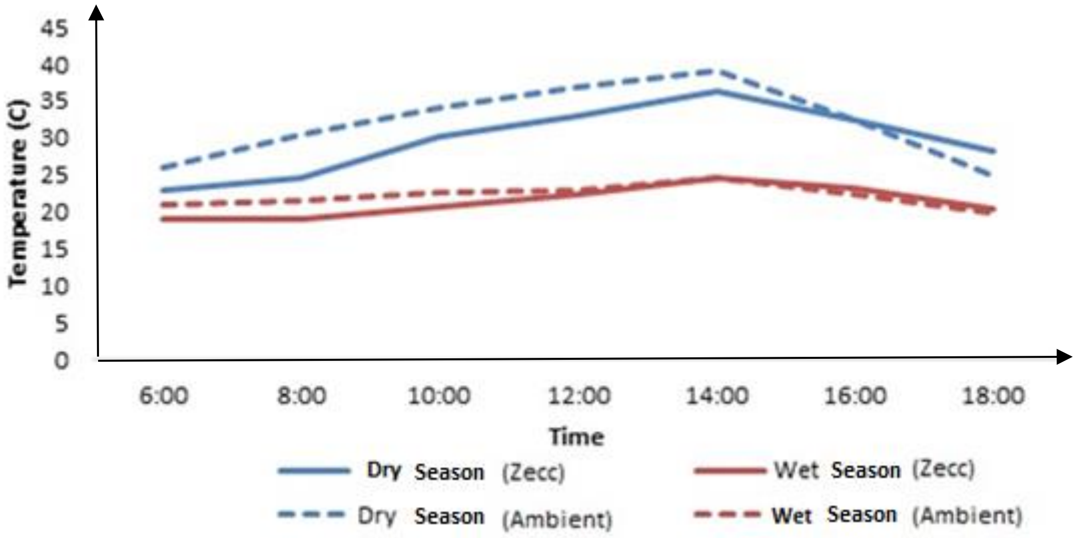

Figure 2.6: Mean daily temperature changes in different storage conditions across time

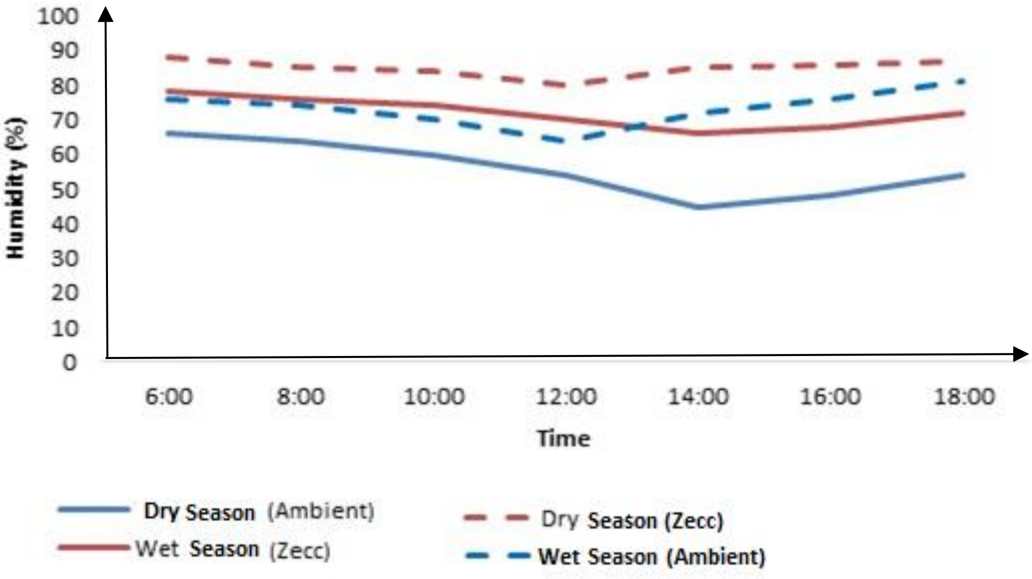

Figure 2.7: Mean daily humidity changes in different storage conditions across time

2.7.3 Marketability

Tomato fruits in wet season were significantly (*p< 0.0001*) more marketable under ZECC conditions compared to ambient conditions (Fig. 2.8). In similar trends, drop in marketability over time (storage conditions*time) was significantly sharp in ambient conditions (Fig. 2.9).

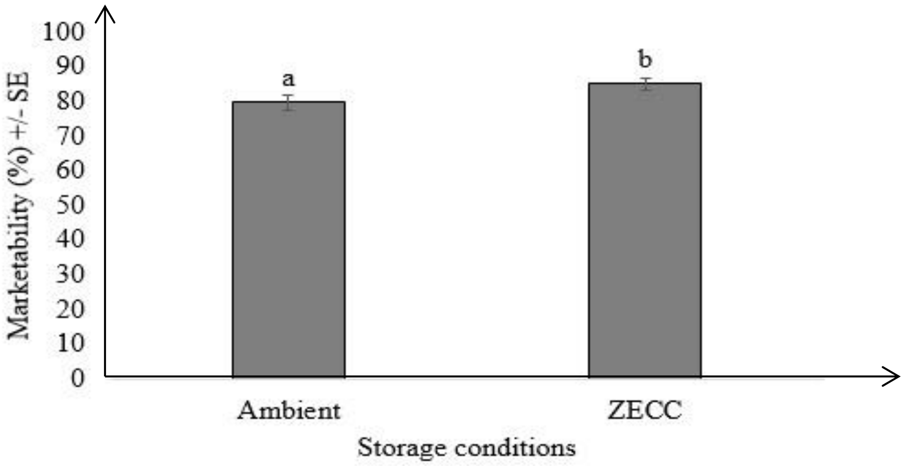

Figure 2.8: Marketability of tomato fruits under different storage conditions. Bars with different letters as data labels represent means that are significantly different at P<0.05 by Fishers' LSD method.

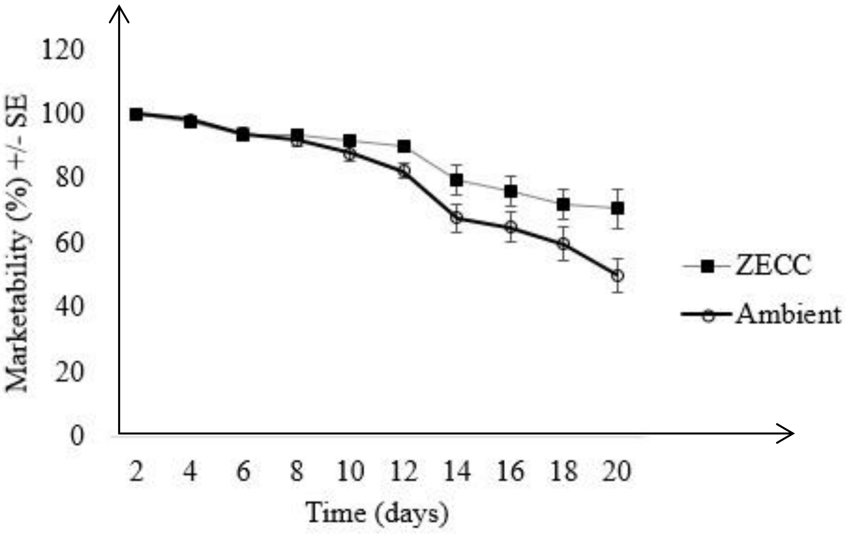

Figure 2.9: Marketability drop rate of tomato fruits under different postharvest storage conditions

In dry season, tomato fruits stored under ZECC conditions also had significantly lower deterioration rates of marketability compared to those stored in ambient conditions. The *P* value computed was ($1.822e^{-09}$). The variation of the three-way interaction between storage conditions, maturity stage and time was also significant ($p < 2.2e^{-16}$). Deterioration of marketability is higher in the mature red stage of maturity and lowest in the mature green stage as depicted by the AUCs (Fig. 2.10, 2.11 and 2.12).

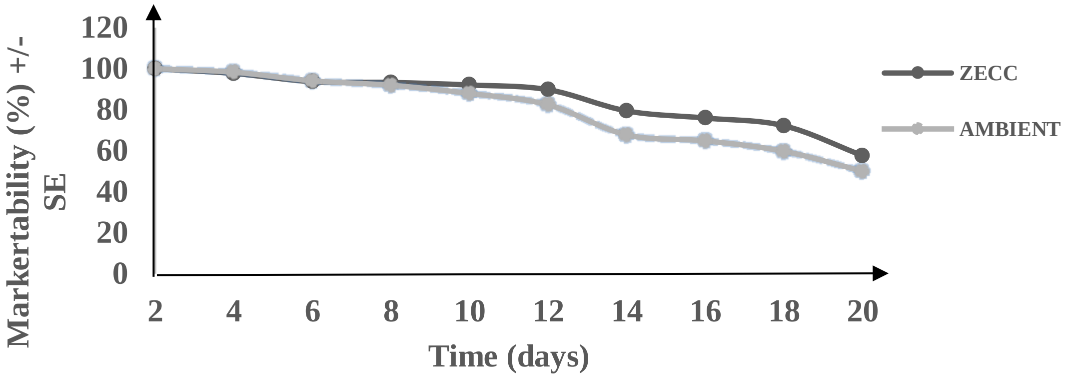

Figure 2.10: Marketability of tomato fruits under different postharvest storage conditions over time

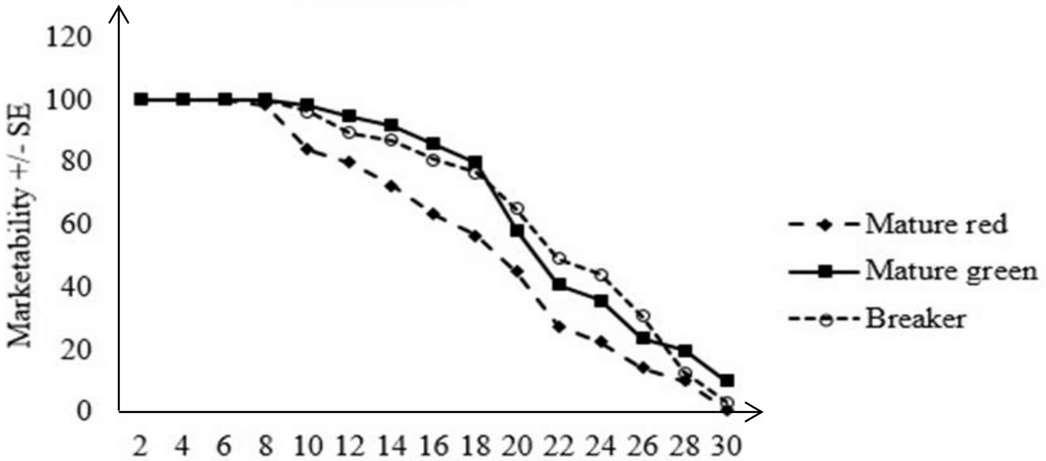

Figure 2.11: Marketability trend of tomato fruits under ambient conditions in dry season for each maturity stage

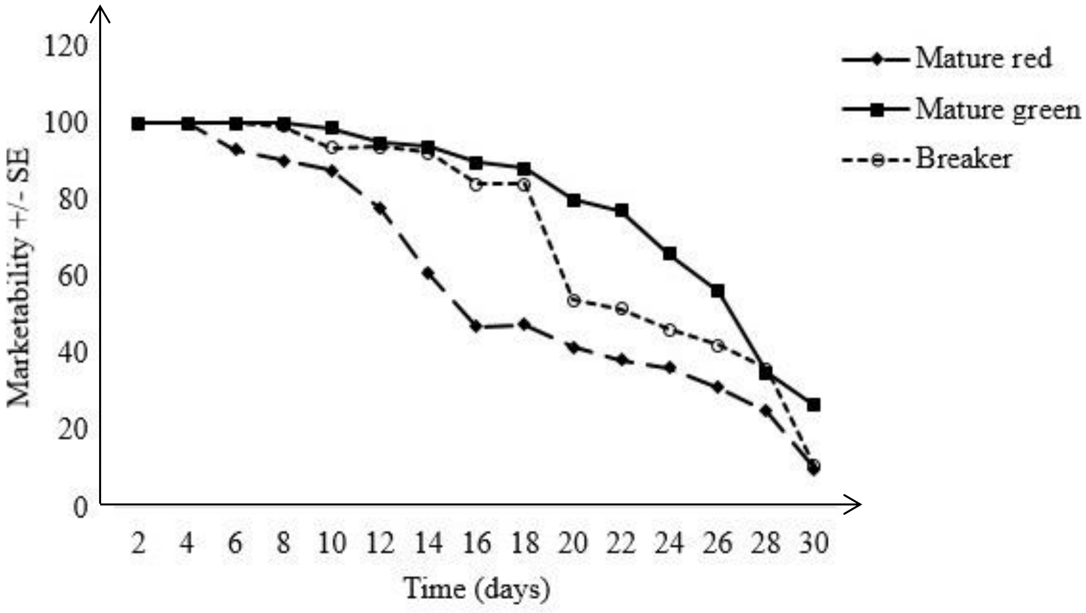

Figure 2.12: Loss of marketability of tomato fruits under zero energy cooling chambers conditions for every maturity stage during the dry season

2.8 Discussion

Temperature and relative humidity are among the major environmental factors affecting postharvest quality of most fruits and vegetables (Payas, 2010). The two parameters can influence metabolic rates of fruit cells, population dynamics of storage fungi (Leff, 2013) and physical integrity of fruits (Huang, 2014). In this study, the physiological weight loss in ambient conditions was significantly higher compared to storage in ZECC conditions. It was evident that the temperature was higher under ambient conditions while relative humidity was low compared to ZECC where the temperature was significantly lower and with higher relative humidity. These results relate to findings by Arah *et al*. (2015) who found that respiration and metabolic activities within tomato fruits are directly linked to storage temperature. The high temperature under ambient storage could have triggered CO_2 and ethylene production by tomato fruits (Atta *et al.*, 1992). The aggravated ethylene production increases the rate of ripening which in turn increases the rate of physiological weight loss. Due to the inherently high water content in most vegetables, tomato inclusive, storage at ambient temperature reduces the produce shelf life and escalates postharvest losses.

Since tomato is a climacteric fruit, it is possible to harvest the fruits at any stage after attainment of physiological maturity. This can be a good strategy for reduction of PWL and thereby increasing shelf life of the fruits both at ambient and ZECC storage conditions. Results of this study have demonstrated a critical role of taking into account the harvesting maturity stage of the fruits during harvesting for shelf life extension. Physiological loss of weight was significantly reduced when tomato was harvested at mature green stage and was significantly lower when stored under ZECC conditions. The higher relative humidity and lower temperature under ZECC storage prolong shelf life by reducing respiration and transpiration rates (Arthur *et al*., 2015). Tomato fruits stored in ZECC at mature green had a shelf life of 12 days to attain 5% physiological loss in weight. This study agrees with the study by Achoja and Okoh (2013) who found that most fruit vegetables can naturally maintain premium quality for only 2-4 days under ambient conditions, but can be extended to 8-15 days if efficient storage facilities are available. Under ambient temperatures, the kinetics of pectic enzymes is higher compared to storage in reduced temperature and elevated relative humidity conditions (Kalamaki *et al*., 2012). These enzymes degrade the epicuticular wax of tomato which is important in controlling loss of water by transpiration (Leide *et al.*, 2007). Degradation of the epicuticular wax makes tomato fruits softer leading to loss of structural integrity and become unmarketable. During wet season there was no significant difference in weight loss between harvesting states due to low temperatures. There was difference in weight loss between harvesting stages during the wet season but not significant where the temperatures were slightly lower. This indicates that farmers do not need to worry much maturity stages but rather storage conditions when harvesting in the wet season. Reducing temperature and increasing relative humidity are primarily means of maintaining produce quality. Management of temperature and relative humidity through zero energy cooling chambers is an alternative approach of mechanical refrigerator to extend shelf life of perishables especially on-farm.

The capacity of storage of ZECC is 360 kg of tomatoes (9 crates of 40 kg), the cost of construction of the structure is 130 000 TZS, and the depreciation cost per annum is 13 000 TZS. The subsequent maintenance from 2nd year is 10 000 TZS (5 000 per season) and the life span of the structure is 3 years. If the sale price of tomatoes at the time of harvest is 25 000 TZS per crate (40 kg), total sales of nine crates at the time of harvest will be 225 000 TZS. If the anticipated return after sales with loss of 10% on an average of 4-6 days is 30 000 TZS the total sales will be 270 000 TZS minus loss (10%) which will be 243 500 TZS. So the farmer will get the benefit of 18 000 TZS within 4-6 days of storage. If the farmer will store nine crates of tomatoes seven times yearly he/she will get a total benefit of 126 000 TZS .

2.9 Conclusion

The comparison between ambient and zero energy cool chamber storage conditions was significant in both seasons. Zero energy cool chambers were found effective in reducing weight loss of tomato hence increasing the shelf life of the produce. The study showed that, interaction between storage conditions, time and maturity stage in the wet season was not significant while in dry season was significant. Also the shelf life of tomato fruits (days to 5% physiological loss of weight) in the mature green stage stored under ZECC conditions were higher compared to other storage conditions. The marketability of the fruits was also affected by storage conditions whereby tomato fruits were found more significantly marketable under ZECC conditions compared to ambient conditions.

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CHAPTER THREE

3.0 THE EFFECT OF DIFFERENT LINING MATERIALS ON ON-TRANSIT TOMATO LOSS REDUCTION

3.1 Abstract

Poor transportation and packaging can lead to 30-40% postharvest losses mainly due to mechanical damage. In Morogoro region tomato are packed in wooden crates occasionally lined with grass. This increases possibility of the produce been mechanically damaged and also increases abrasion between the fruits and the container walls. Lining materials are known to reduce physical injury hence maintaining quality of the produce. Use of grass as lining materials has been banned in most markets in the country due to environmental pollution. Moreover, the grasses can puncture some fruits if the grass lining is not carefully done. The current study was conducted to evaluate the effectiveness of different lining materials in reducing postharvest losses of tomato. The experiment contained four lining materials namely brown paper, hessian cloth and sponged papers. Wooden crates without lining material were included as a control. Hessian cloth was found to be more effective in reducing on-transit losses of tomato with 10.6% fruit loss. Tomato fruits transported in crates with no lining had significantly *(*p= 0.0004) higher fruit loss. Cost benefit analysis showed that for transport of 36 wooden crates carrying 1.44 tons of tomato, the net profit when crates are lined with hessian cloth was 216 000 TZS compared to crates with no lining materials on which it was on the margin with no profit.

3.2 Introduction

Tomato (*Solanum lycopersicum* L.) is an important horticultural crop which belongs to the Solanaceae. Botanically this fruit is a berry (Salunkhe *et al*., 2005). Tomato is a perennial plant but commercially grown as an annual crop in various parts of the world (Nunes *et al.*, 1996; Knaap *et al.*, 2002). It is the second most important vegetable crop next to potato (FAO, 1989). Tomato is rich in vitamin A, C and minerals, dietary fiber, low in fat and calories and a good source of lycopene. Tomato is one of the most important ingredients in meals in most households.

Tomato is among the major fruits produced in Tanzania and has good export potential if the postharvest deterioration and storage losses are controlled effectively. Moisture loss from fruit surfaces, resulting in shriveling, green and blue mold decay and internal black rot are mainly being responsible for quality degradation and spoilage.

The use of lining materials has given encouraging results for extending shelf life of fruits (Ahmad *et al*., 1976). Maqbool *et al.* (1979) concluded that citrus fruits kept in boxes lined with cellophane retained better flavor than wax-coated fruits held in containers lined with newspaper sheets.

In Morogoro region tomato production is an important economic activity for most small scale farmers. Improper handling of produce contributes much on postharvest loss of tomato. Poor transportation and packaging can lead to losses of up to 40% (MUVI-SIDO, 2009; AVRDC, 2014). Proper handling practices reduce the incidence of bruising, and some have suggested that flavor is reduced with increased improper handling (Abdullah *et al*., 2010). In the region tomato is transported by using non-refrigerated trucks, packed in wooden crates lined with grasses and sometimes without lining materials. The use of grasses has been banned in most of the markets in the country since they pollute environment. The current study was conducted to evaluate the effectiveness of different lining materials in reducing on transit losses of tomato.

3.3 Materials and Methods

3.3.1 The experiments

Thirty-six (36) sorted crates of 45 kg of tomato were purchased from a village collection center at Mlali. The experiment contained four treatments. The treatments were wooden crates with no lining material (control), crates lined with brown paper, crates lined with hessian cloth and crates lined with sponged papers. Each treatment consisted of nine crates. The experiment was laid out in randomized complete block design with three replications, each replication contained three blocks (lower, middle and upper layer). The replications were on the front, middle and rear side of the truck. The produce was transported from farmer collection center at Mlali village, Morogoro to Ilala market, Dar es Salaam about 225 km (both tarmac and rough road) for evaluation.

3.3.2 Data collection

3.3.2.1 Percentage marketability

The percent marketability (overall condition) was subjectively assessed according to Mohammed *et al*. (1999). Descriptive quality attributes were determined subjectively by observing the level of visible defects. Fruits were regarded non marketable based on the quality acceptable at the Ilala market. Two experienced retailers at the market were involved in sorting marketable and non-marketable tomato fruits. The percentage of marketable fruits was calculated as follows.

$$\text{Marketable tomato fruits (\%)} = \frac{Weight\ of\ marketable\ tomato\ fruits}{Total\ weight\ of\ tomato\ fruits}\ X100 \ldots\ldots\ldots\ldots(1)$$

3.3.2.2 Percentage physical loss

The percent physical loss was determined after transporting tomato from Mlali village to Ilala market. The acceptability criteria for the Ilala market included the variety of the tomato fruit, the quality of the fruits (deformities, bruises, raptures, cracks, visible pests, disease symptoms) and the price of the tomato fruits. Tomato were packed in different lining materials hessian cloth, brown paper sponged paper and control with no lining materials. After arriving Ilala market, tomato was sorted for physical damaged one (bruised, cracked, raptured, diseased) and undamaged ones per lining material. The percentage physical loss was calculated as follow

$$\text{Physical loss (\%)} = \frac{No\ of\ damaged\ tomato\ fruits}{Total\ number\ of\ tomato\ fruits}\ X100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

3.3.3 Data analysis

An analysis of variance (ANOVA) was performed with the lining materials as the factor and fruit physical loss as the variable. The physical loss data was log transformed to normality before the ANOVA. The means were separated by Fishers' Least Significance Difference (LSD). Significance of difference between percentage marketable fruits that reached the market was analyzed by Kruskal Wallis' non parametric test ($p \leq 0.05$).

3.3.4 Cost benefit analysis

The cost benefit analysis considered the labour cost 1 000 Tanzania Shillings per crate, cost of lining materials where the cost was 500 TZS for both sponged and brown paper while for 1 000 TZS for hessian cloth per crate, the number of crates (36) that can hold the produce where the cost for each cost was 2 000 TZS per crate, cost of tomato produce on farm which was 25 000 TZS per crate, the cost of transportation of the crates to the market which was 3 500 TZS per crate and the selling cost of tomato where by the market price was 40 000 TZS per crate. The physical losses of tomato when crates were lining materials were also included in the analysis. The total cost was estimated by summing up the labour, tomato, crates, transport, lining material, loss per lining material cost. Total sales were obtained by multiplying the number of packed crates (36) and the market price at time of selling which was 40 000 TZS. The net profit was obtained by deducting the total cost from the total sales of tomato at Ilala market. Tables for each lining material, showing the fixed cost, operation cost, benefits and net profit were used.

3.4 Results

3.4.1 Physical loss of fruits

It was found that lining materials significantly reduced on transit tomato loss (Fig. 3.1). Lined crates with hessian, brown and sponged papers led to significantly ($p< 0.0001$) lower on transit fruit loss compared to the control (Fig. 3.1). Crates lined with hessian cloth (10.6%) protected the fruits better compared to brown (14%) and sponged (15%) lining materials. However, the fruit losses obtained from using crates lined with hessian cloth was similar ($p \leq 0.05$) compared to lining using brown paper. There was significantly ($p< 0.0001$) higher fruit loss from crates lined with sponged paper compared to those lined with hessian cloth (10.6%).

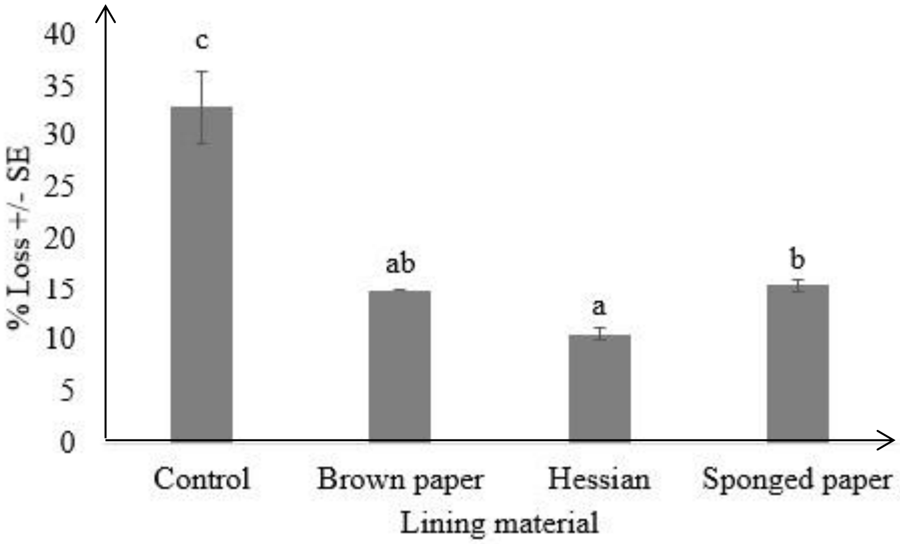

Figure 3.1: Tomato fruits loss at Ilala market in Dar es Salaam using crates lined with different materials. Bars that do not share a letter as its data label represent means that are significantly different by Fishers' pairwise comparison method

3.4.2 Marketability

In this study marketability conditions of transported tomato fruits varied significantly at p= 0.02374 by Kruskal Wallis's test under different lining conditions. The chi square value obtained was 9.46 with 3 degrees of freedom. More unmarketable fruits were found in unlined crates (Control) while crates lined with Hessian materials had fruits with the most marketable conditions (Fig. 3.2).

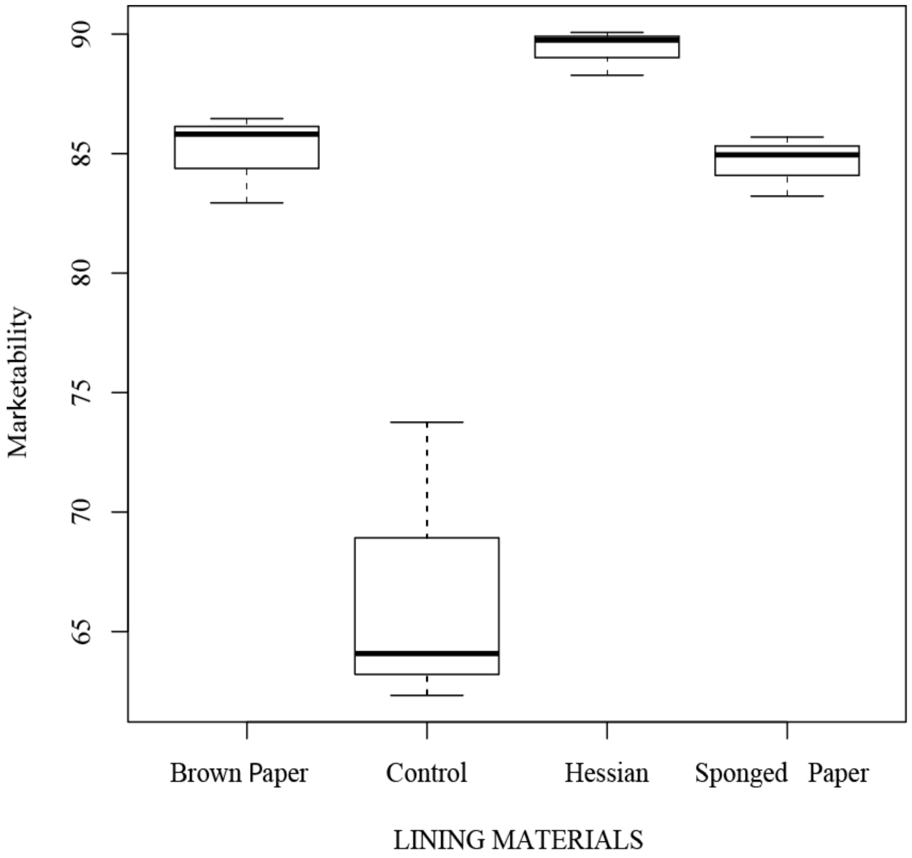

Figure 3.2: Boxplot depicting percent of marketable tomato fruits transported from Mlali, Morogoro to Dar es Salaam Ilala market

3.4.3 Cost benefit analysis

Economic aspects of proper postharvest techniques are justified after the cost benefit analysis. By using lining materials, a farmer can get higher profit compare to the one not using lining materials (Table 2, 3 and 4). Cost benefit analysis showed that for transport of 36 wooden crates carrying 1.44 tons of tomato, the net profit when crates are lined with hessian cloth was 118 000TZS compared to crates with no lining materials on which it was a loss of 12 000 TZS (Table 1 and 4). The net profit for transporting crates lined with sponged paper and brown paper was 72 000 and 88 000 TZS respectively.

Table 1: Cost benefit analysis excluding cost of using lining materials

S/N	Item	Quantity	Unit	Price (TZS)	Total (TZS)
A	**FIXED COST**				
	Tomato fruits	36	crate	25 000	900 000
	Tomato crates	36	Box	2 000	72 000
	Total				**972 000**
B	**OPERATION COST**				
	Transport cost	36	crates	3 500	126 000
	Labour cost	36	crates	1 000	36 000
	Total				**162 000**
C	**BENEFIT**				
	Sales of 36 crates – Loss on transit (34.3 %)	24	crates	40 000	960 000
	Total				**960 000**
D	**NET PROFIT**				
	Sales-(fixed cost + operation cost)				-12 000

Cost: Benefit = A+B: C= 1 134 000: 960 000 = 1:0.84

Table 2: Cost benefit analysis of using sponged lining materials

S/N	Item	Quantity	Unity	Price (TZS)	Total (TZS)
A	**FIXED COST**				
	Tomato fruits	36	crate	25 000	900 000
	Tomato crates	36	box	2000	72 000
	Sponged paper	36	paper	500	18 000
	Total				**990 000**
B	**OPERATION COST**				
	Transport cost	36	crates	3500	126 000
	Labour cost	36	crates	1000	36 000
	Total				**162 000**
C	**BENEFIT**				
	Sales of 36 crates – Loss on transit (15%)	30.4	crates	40000	1 224 000
	Total				**1 224 000**
D	**NET PROFIT**				
	Sales-(fixed cost +operation cost)				72 000

Cost: Benefit = A+B: C= 1152 000: 1 224 000 = 1:1.06

Table 3: Cost benefit analysis of using brown paper lining materials

S/N	Item	Quantity	Unit	Price (TZS)	Total (TZS)
A	**FIXED COST**				
	Tomato fruits	36	crate	25 000	900 000
	Tomato crates	36	box	2000	72 000
	Brown papers	36	paper	500	18 000
	Total				**990 000**
B	**OPERATION COST**				
	Transport cost	36	crates	3500	126 000
	Labour cost	36	crates	1000	36 000
	Total				**162 000**
C	**BENEFIT**				
	Sales of 36 crates – Loss on transit (14%)	31	crates	40 000	1 240 000
	Total				**1 240 000**
D	**NET PROFIT**				
	Sales-(fixed cost+ operation cost)				88 000

Cost: Benefit = A+B: C= 1 152 000: 1 240 000 = 1:1.07

Table 4: Costs benefit analysis of using hessian lining materials

S/N	Item	Quantity	Unit	Price (TZS)	Total (TZS)
A	**FIXED COST**				
	Tomato fruits	36	crate	25 000	900 000
	Tomato crates	36	box	2000	72 000
	Hessian cloth	36	paper	1000	36 000
	Total				**1008000**
B	**OPERATION COST**				
	Transport cost	36	crates	3500	126 000
	Labour cost	36	crates	1000	36 000
	Total				**162 000**
C	**BENEFIT**				
	Sales of 36 crates- Loss on transit (10.6%)	32.2	crates	40 000	1 288 000
	Total				**1 288 000**
D	**NET PROFIT**				
	Sales-(fixed cost + operation cost)				118 000

Cost: Benefit = A+B: C= 1 170 000: 1 288 000 = 1:1.10

3.5 Discussion

During transportation of tomato from field to market, losses can be attributed to high temperature, pathological decays and mechanical damage (Aboubakar and Okene, 2015). One thing was evident, using lining materials (hessian cloth, sponged and brown paper) reduce loss by over 15%. Lining materials reduce friction between tomato fruits and crates thereby reducing chances of bruises and mechanical damage (Kasso and Bekele, 2015).

The current study showed the hessian cloth to be the most favorable lining material for tomato fruits transportation. The hessian cloth is made up of jute fabrics which is soft with high resistance to friction (Mishra, 2014). Its porous structure allows ventilation hence preventing condensation which would otherwise favor growth of mould (Acedo and Weinberger, 2010). When transporting tomato fruits by road over long distances it is prudent to fumigate the crates. Hessian cloth would be a perfect material for lining as it would allow penetration of the fumigants. Also, its degradable nature makes it an environmentally friendly option. The cost benefit analysis clearly portrayed a superior financial advantage of using hessian cloth as lining.

3.6 Conclusion

The assessment of lining materials on reducing on transit postharvest losses revealed that hessian lining materials resulted to the lowest percentage loss (10.6%) compared to other lining materials. More fruits that are unmarketable were found in unlined crates (control). Cost benefit analysis showed that, the net profit when crates are lined with hessian cloth was higher (118 000 TZS) compared to crates with no lining materials Profit accrued from crates with no lining materials which was as loss of 12 000 TZS due to higher mechanical damage on transported fruits.

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CHAPTER FOUR

4.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The comparison between ambient and zero energy cool chamber storage conditions was significant in both seasons. Zero energy cool chambers were found effective in reducing weight loss of tomato hence increasing the shelf life of the produce. The study showed that, interaction between storage conditions, time and maturity stage in the wet season was not significant while in dry season was significant. Also the shelf life of tomato fruits (days to 5% physiological loss of weight) in the mature green stage stored under ZECC conditions were higher compared to other storage conditions. The marketability of the fruits was also affected by storage conditions whereby tomato fruits were found more significantly marketable under ZECC conditions compared to ambient conditions.

The assessment of lining materials on reducing on transit postharvest losses revealed that hessian lining materials resulted to the lowest percentage loss (10.6%) compared to other lining materials. More fruits that are unmarketable were found in unlined crates (control). Cost benefit analysis showed that, the net profit when crates are lined with hessian cloth was higher (118 000 TZS) compared to crates with no lining materials. Profit accrued from crates with no lining materials on which there was no profit due to higher mechanical damage on transported fruits.

4.2 Recommendations

In order to reduce on-farm losses zero energy cooling chambers are recommended to be adopted by farmers. The ZECC technology performs best during the dry season. In this season temperatures are normally high and with low relative humidity which leads to higher postharvest losses. The ZECC is therefore recommended to use during the dry season to minimize on-farm postharvest losses. In order to increase tomato shelf life, farmers should harvest at green and breaker stages. Lining materials has great importance in reducing on-transit losses. During transportation farmers should use lining materials specifically the hessian cloth since lower losses were observed during transportation.

Apart from weather conditions and package lining materials, there is a need of more studies on the relationship between storage conditions, diseases and varieties on postharvest losses of tomato. Also since the study revealed that hessian cloth has great advantage on reducing on transit postharvest losses, acceptance of the technology to farmers is essential. There is a need to scale out and scale up the technology of using hessian cloth as lining materials during tomato transportation.