Wolkite University

College of Agriculture and Natural Resources

Department of Horticulture

Effect of Calcium Chloride ($CaCl_2$) on Shelf-Life and Quality of Tomato Fruits (*Lycopersicon esculentum*, Mill)

Senior Research Project II

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Prepared by:

1. *Abiyot Fetene (ID. No., 011/09)*
2. Meskerem Gebrie *(ID No., 268/09)*
3. Azimera Ytibarek *(ID. No.,064/09)*

Advisor: Zenebe Woldu Adane (PhD)

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List of Acronyms and Abbreviations

ANOVA	Analysis of Variance
CRD	Complete Randomized Design
CV	Coefficient of Variation
DMC	Dry Matter Content
FAO	Food and Agricultural Organization of the United Nations
LSD	Least Significant Difference
m a.s.l..	meters above sea level
mm	millimeter
PWL	Physiological Weight Loss
RH	Relative Humidity
TSS	Total Soluble Solids
WKU	Wolkite University

ABSTRACT

The present study was carried out to determine the effects of different concentrations of calcuim chloride ($CaCl_2$) on quality and shelf life of tomato fruits harvested at the standard physiologically matured green stage (Maturity Index I). The nationally released Galilee variety was used for the experiment. The treatments were: dipping the fruits for 20 minutes in1000 ml of distilled water, which contain *0% (control),* 2% , 4% and 6% of $CaCl_2$. The treated fruits were then stored throughtout the experimental period at room temperature (20 ± 2^oC) within the horticulture laboratory of Wolkiete University (Ethiopia). The experiment was laid out under a Complete Randomized Design (CRD) with four replications. The fruits where stored for a total of 63 days up until they finish their marketable life across all the treatments. Statistical analysis showed significant differences amongst all treatments across all the data collection parameters (TSS, pH, DMC, Firmness, Color Index, Decay % and Shelf-life) except PWL (%). The highest level of TSS (3.87^oBrix) and fruit decay (75.0%) were found when fruits were treated with the control (0% $CaCl_2$) followed by those treated with 2%, 4% and 6% concentration levels in that order of importance. Conversely, the highest Shelf-life (55.75 days) as related to the lowest pH (4.52), PWL (16.91%) and DMC loss (0.92%), were obtained from those treated with the highest concentration of calcium chloride (6% $CaCl_2$). Concurrently, the lowest changes in fruit color (Color Index 5) and fruit firmness (3.0) at the end of the 63 days long storage period were recorded from fruits treated with the highest concentration of calcium chloride (6% $CaCl_2$) while showing the same descending trend as the concentration decreased.Therefore,aqurding to this particular experiment,it is recommended that physiologically matured green tomato fruits (Maturity Index I) be treated with the highest concentration of calcium chloride (6% $CaCl_2$) for better quality, storage life and postharvest decay control.

Keywords: *Tomato fruits,*calcium chloride ($CaCl_2$), *quality, shelf-life and post harvest decay.*

1. Introduction

Tomato *(Lycopersicon esculentum* Mill.) belongs to the family of Solanaceae. It is a perennial, monocarp and herbaceous plant originating in the western coastal plains of South America extending from Ecuador to Chile (Bose and Som1990).

It is one of the most popular vegetables worldwide playing a vital role in the human diet (Sibromana et al., 2015). It is consumed in highly diverse forms as salads,whole peeled, cooked into soups, processed into juice, ketchup, puree and paste It is rich in vitamins (esp. A and C), minerals, sugars, essential amino acids, iron and dietary fiber (Ayendiji et al. 2011). The fruits also contain high amount of lycopene, which is a type of caretonoid with anti-oxidant properties and beneficial in reducing the incidence of some chronic diseases like cancer and many other cardiovascular disorders For fruits like tomato, postharvest handling is as critical as production practices due to their delicate and highly perishable nature (Ruth Ben et al., 1986).

Postharvest losses of tomato may takeplace at any stage in the handling system from harvesting through storage,packaging,transportation and marketing up until the final delivery to the ultimate consumers.As such,nearly 30-50% of the produce is lost after harvest because of inadequate handling and preservation systems due to various cause like mechanical,physical tomato is one of the most important, popular and widely consumed vegetables. However, due to lack of appropriate technologies on postharvest treatments, storage, packaging, cool-chain management and transporation, all actors across its supply chain are still facing substantial levels of quantitative and qualitative postharvest losses(Basu and Imrhan, 2007)

As stated by Ruth Ben et al. (1986), postharvest losses of tomato can be reduced by calcium chloride treatment. Calcium chloride has been widely used as an economical processing aid, preservative and firming agent in the fruits and vegetables industry across the world. Applying calcium chloride treatment contributes to cell wall integrity by increasing the amount of endogenous calcium available to bind with desterified pectic residues. On to of its role to preserving fruit firmness, studies indicate that postharvest calcium chloride dips reduce respiration, decrease ethylene production and delay senescence in fresh produce of such crops like tomato, carrot, Kiwi fruit), strawberry and. The concentration of the calcium chloride dips depends on the fruit or vegetable being treated although several studies indicate that 1–6% calcium chloride salts are most effective for diced tomatoes, cantaloupes and pears (Agar *et al.*, 1999).

2. Objective

To investigate the effect of postharvest treatment ofcalcuim chloride($CaCl_2$) on quality, shelf-life and microbial decay control of tomato fruits when applied at different levels of concentrations.

3. Literature Review

3.1. The tomato fruit

Tomato *(Lycopersicon esculentum* Mill.) is a herbaceous plant belonging to the family of Capsicum spp.It is a perennial, monocarp and herbaceous plant originating in the western coastal plains of South America extending from Ecuador to Chile (Bose and Som1990).

3.2. Importance of the tomato fruits

Tomato is one of the most popular and widely grown vegetables in the world. It plays a vital role in the human diet while consumed in highly diverse forms like salads,whole peeled, cooked into soups, processed into juice, ketchup, puree and paste (Adedeji et al.,2006; Sibromana et al., 2015). It is rich in vitamins (esp. A and C), minerals, sugars, essential amino acids, iron and dietary fiber The fruits also contain high amount of lycopene, which is a type of caretonoid with anti-oxidant properties and beneficial in reducing the incidence of some chronic diseases like cancer (Basu and Imrhan, 2007) .

The quality of tomato fruit is largely dependent on the stage of maturity of fruits and various ripening conditions which are principally applied to increase its storability or shelf life. It is, therefore, important to control deterioration processes in order to maintain quality. Many researchers have been conducted on the use of postharvest treatments to extend shelf life of tomato in different parts of the world. Thus, the quality of tomato should be controlled before consumption (Freeman and Reimers, 2010).

3.3. Postharvest handling of tomato fruits

The postharvest quality of tomato fruit is largely dependent on the stage of maturity of fruits and various ripening conditions which are principally applied to increase its storability or shelf life. Various studies have been conducted on the use of different postharvest treatments and handling techniques to extend the shelf life of tomatoes. It was identified tha most of the postharvest losses of tomato, both in terms of quality and quantity, are caused due to poor or rough handling in the field, improper packaging, careless loading and unloading during transportation and poor storage facilities.(Ayendiji *et al.* 2011).

Physical handling can have a drastic effect on the postharvest quality and shelf life of most harvested fruits and vegetables. For instance, rough handling during harvesting and after harvesting can cause mechanical injuries which can affect the postharvest quality and shelf life of such delicate fruits like tomatoes. It is therefore important to know suitable postharvest handling practices needed to maintain the quality and extend the shelf life of harvested tomatoes. These largely includes activities like proper harvest maturity determination, harvesting, precooling, cleaning and disinfecting, sorting and grading, packaging, transportation, and storage (Freeman and Reimers, 2010).

3.3.1. Harvesting

Physiological maturity of any fruit at harvest has an important effect on postharvest quality of that fruit . Therefore, care must be taken as to when to harvest the fruit in order to attain the best quality. The shelf life of fruits and vegetables is described by postharvest physiologists in three stages: the maturation, ripening, and senescence stages. The maturation stage gives anindication of the fruit being ready for harvest . Tomatoes can be harvested in either matured green, partially ripe, or ripe state (Varit S.Songsin P.2011).

Tomato being a climacteric fruit can be harvested at the matured green state allowing ripening and senescence to occur during the postharvest period of the fruit. Producers targeting distant markets must harvest their tomatoes in a matured green state. Harvesting tomatoes in matured green state will not only give producers ample time to prepare the fruit for the market but also prevent mechanical injuries during harvesting. Unfortunately, most producers from developing countries especially those in Africa harvest tomatoes when they are partially or fully ripened . Fully ripened tomatoes are susceptible to mechanical injuries during harvesting resulting in shorter shelf life . Care must therefore be taken when harvesting tomatoes in ripe state to avoid these injuries which will hasten deterioration. Also, the use of harvesting and packaging containers with sharp edges must be discouraged to prevent bruising and puncturing of the fruits. Harvesting of fruits should be done in either early or late hours of the day to avoid excessive field heat generation (Srivastava RP,*et al.*, 2004)

3.3.2. Precooling

.Field heat is usually high and undesirable at harvesting stage of many fruits and vegetables and should be removed as quickly as possible before any postharvest handling activity . Excessive field heat gives rise to an undesirable increase in metabolic activity and immediate cooling after harvest is therefore important . Precooling minimises the effect of microbial activity, metabolic activity, respiration rate, and ethylene production , whilst reducing the ripening rate, water loss, and decay, thereby preserving quality and extending shelf life of harvested tomatoes. Harvested fruit must be precooled to remove excessive field heat if harvested at times other than the recommended periods. A cheap but effective way of precooling harvested tomatoes for producers of developing countries can be by dipping fruits in cold water (hydrocooling) mixed with disinfectants such as thiabendazole and sodium hypochlorite if availability of clean water is not a challenge. This method is effective in removing field heat whilst reducing microbial loads on the harvested fruits (Amiruzzaman,2000).

3.3.3. Cleaning and Disinfecting of tomato fruits

Proper hygiene is a major concern to all produce handlers, because of not only postharvest diseases, but also incidence of food-borne illnesses that can be transmitted to consumers. Unfortunately, cleaning or disinfecting tomatoes after harvest is not a common practice for most tomatoes handlers in developing countries especially those from Africa. This practice may be attributed to either the unavailability of portable water at the production sites or the sheer ignorance of the practice. However, in places where water is not a constraint, the use of disinfectants in water either for washing or for cooling can reduce both postharvest and food-borne diseases in fruits and vegetables (Wills RBH,. 2002).

The use of various disinfectants during postharvest treatment of tomatoes is well documented. For instance, Sodium Hypochlorite solution (NaOCl) has been used to sterilise tomato fruits in order to reduce the incidence of fungal infection before any postharvest treatment was applied . Dipping of tomato fruits in Calcium Chloride ($CaCl_2$) and Thiabendazole solutions also variously reported effectively reducing the microbial load and by so doing maintaining the quality and extending the shelf life of tomato fruits (Wills RBH,. 2002).. Fruits and vegetables are usually treated with chlorinated water after washing to reduce the microbial load prior to packaging. Anolyte water dipping disinfection of tomatoes not only reduced the microbial loads on the fruits but also maintained superior quality of tomatoes during storage. Disinfection can be used in conjunction with hydrocooling to achieve the purpose of reducing excessive field heat and reducing microbial infection at the same time .

3.3.4. Sorting and Grading

One of the most important processes in packaging and marketing of fruit and vegetables is sorting and grading. Sorting is the removal of rotten, damaged, or diseased fruits from the healthy and clean ones. The damaged or diseased fruits can produce ethylene in substantial amounts which can affect the adjacent fruits . Grading is also the process of categorising fruits and vegetables on the basis of colour, size, stage of maturity, or degree of ripening. The two processes are vital in maintaining postharvest shelf life and quality of harvested tomatoes. Sorting limits the spread of infectious microorganisms from bad fruits to other healthy fruits during postharvest handling of tomatoes. Grading also helps handlers to categorise fruits and vegetables in a given common parameter which enables easy handling. For instance, grading on the basis of colour or maturity stage will help eliminate overripe fruits which will easily produce ethylene to hasten the ripening process in the whole batch. Commercial tomato producers normally use sophisticated systems that require precise sorting and grading standards for their produce. Small-scale producers and retailers in developing countries in contrast may not use written down grading and sorting standards; however, the produce must still be sorted and sized to some degree before selling or processing it (Abushita AA**.** 1997).

3.3. 5. Packaging

Packaging is also one of the important aspects to consider in addressing postharvest losses in fruits and vegetables. It is enclosing food produce or product to protect it from mechanical injuries, tampering, and contamination from physical, chemical, and biological sources . Packaging as a postharvest handling practice in tomato production is essential in putting the produce into sizeable portions for easy handling. However, using unsuitable packaging can cause fruit damage resulting in losses.Some common packaging materials used in most developing countries include wooden crates, cardboard boxes, woven palm baskets, plastic crates, nylon sacks, jute sacks, and polythene bags (Sammi and Masud , 2007).

Most of the abovementioned packaging materials do not give all the protection needed by the commodity. Whilst the majority of these packaging materials like the nylon sacks do not allow good aeration within the packaged commodity causing a build-up of heat due to respiration, others like the woven basket have rough surfaces and edges which cause mechanical injuries to the produce(Mathooko,2003). The wooden crate and the woven palm basket are some of the common packaging materials used in many developing countries especially those in Africa for packaging tomatoes. The major shortcoming of the wooden crate is in its height which creates a lot of compressive forces on fruits located at the base of the crate.These undesirable compressive forces cause internal injuries which finally result in reduced postharvest quality of the tomatoes . There have been suggestions of modifying the wooden crate to make it more suitable for packaging tomatoes. The palm woven baskets used by tomato handlers have sharp edges lining the inside which puncture or bruise the fruit when they are used (Idha and Aderibigbe ,2007).

3.3.6. Storage

Tomato has very high moisture content and therefore is very difficult to store at ambient temperatures for a long time. Meanwhile, storage in the value chain is usually required to ensure uninterrupted supply of raw materials for processors. Storage extends the length of the processing season and helps provide continuity of product supply throughout the seasons. For short-term storage (up to a week), tomato fruits can be stored at ambient conditions if there is enough ventilation to reduce the accumulation of heat from respiration(Mondal,2000). For longer-term storage, ripe tomatoes can be stored at temperatures of about 10–15°C and 85–95% relative humidity . At these temperatures, both ripening and chilling injuries are reduced to the minimal levels. These conditions are also difficult to obtain in most tropical countries and therefore losses of appreciable quantities of harvested tomatoes have been reported. This is consistent with the claim that the quality of tomato is compromised when exposed to high temperatures and high relative humidity . Very low temperature storage too is detrimental to the shelf life and quality of many tropical fruits like tomatoes. For instance, refrigerating a tomato will reduce its flavour, a quality trait of tomatoes which is largely determined by the total soluble solids (TSS) and pH of the fruit . An understanding of the correct temperature management during storage of tomatoes is vital in extending the shelf life of the fruit whilst maintaining fruit qualities. Tomatoes handlers in tropical countries can store tomatoes for short to intermediate time by using evaporative cooling system made from woven jute sacks (Wills.*et al* 2002).

3.3.7. Transportation

Transporting harvested tomatoes to the market on such bad road network and the lack of proper transportation like refrigerated vans become a big challenge for both producers and distributors . This challenge therefore causes unnecessary delays in getting the produce to the market. Meanwhile, any delay between harvest and consumption of tomatoes can result in losses . Losses of up to about 20% are incurred by producers due to transportation delays. Producers will therefore make use of any available means of transport for their produce without considering its appropriateness in order to avoid delays. Some modes of transportation include human labour, donkeys, public transport, rented trucks, busses, lorries, fuel tankers, articulator trucks, and pick-up vans . However, the use of appropriate transportation for tomatoes is a major factor to consider in postharvest handling of the fruit. (Hong and Lee , 1999). Transporting tomatoes in refrigerated trucks is not only convenient, but also effective in preserving the quality of fruits. However, both the initial investment and the operation costs of these vehicles are very high and beyond the affordable reach of most producers in developing countries. Handlers of developing countries therefore transport their produce using the most affordable mode of transport without considering the effect it will have on the postharvest quality of the produce. Even though handlers from developing countries may not have the capacity to use refrigerated trucks, they should be well educated on the consequences that any other transportation option they use may have on their produce (Paull RE, 2000).

3.4. Nature and Causes of Postharvest Losses of Tomato Fruits

A postharvest loss can be generally defined as the degradation in both quantity and quality of a food production from harvest to consumption. Losses can vary from 25 to 40% depending on the type of crops. For example, the postharvest losses of fruits and vegetables are generally higher than cereal crops due to perishable nature that causes deterioration more quickly (Singh, 1990). Qualitative loand sses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product. Such losses are generally more common in developed countries. On the other hand, quantitative losses refer to those that result in the loss of the amount or quantity of the produce and are more common in developing countries (Kader, 2000)..

In tomato marketing channels, traders often suffer from maximum losses, because they handle and transport more quantities from one place to another than any other intermediaries. Farmers on the other hand suffer high level of postharvest losses mainly because of lack of adequate road infrastructure, poor handling and lack of know-how in marketing. In both cases, training is an essential step to reduce postharvest losses as well as maintain the quality and extend shelf life of the produce.

Kader (2000). generally stated the important strategies necessary to reduce postharvest losses of tomatoes in developing countries as: (i) application of current knowledge to improve the handling systems (especially packaging and cold chain maintenance) of horticultural perishables and assure their quality and safeties; (ii) overcoming the socioeconomic constraints, such as inadequacies of infrastructure poor marketing systems, and weak research and development capacity; and (iii) encouraging consolidation and vertical integration among producers and marketers of horticultural crops.

3.5. Control of Postharvest Losses of Toato Fruits

The perishability of tomato fruits is attributed to adverse physicochemical changes like loss of weight, increased respiration and transpiration, softening of the pulp, microbial decay and change in sugar and acid contents. These can be reduced considerably by applying modern handling technologies and appropriate use of postharvest treatments(Waskar et al., 1991).

Control of postharvest wastage should commence before harvest in the field. Good handling during harvesting can as well minimize mechanical damages and reduce subsequent postharvest losses due to microbial attack.Several physical, biological and chemical treatments have also been used for postharvest loss control in tomato. Generally the effectiveness of such treatments depends on three main factors: the efficacy of the treatment, the level and sensitivity of the infection and the sensitivity of the host produce. The time of infection and the extent of development of the infection are also critical with respect respect to control. In so doing, several types of pre-storage physical or chemical treatments are used to reduce the number of contaminating microorganisms and to inactive the enzymes (Wills et al., 1998).

3.5.1. Physical treatment

Low and high temperature, modified atmospheres, correct humidity, ionizing radiations, good sanitation and development of wound barriers may control postharvest wastage of tomato fruits Of these, low temperature handling and storage is the most important physical method of postharvest control (Wills *et al*., 1998).

3.5.2. Chemical treatment

Chemical control of postharvest disease has become an integral part of the handling and successful marketing of fruit. The success of chemical treatments for disease control depended on the initial spore load, the depth of the infection within the host tissue, the growth rate of the infection, the temperature and humidity and the depth to which chemical can penetrate the host tissue (Wills *et al*., 1998).

A wide range of chemicals have been used for the control of postharvest diseases in fruits and vegetables including tomato. Chlorination when used in combination with non-chemical methods is effective in reducing postharvest disease loss. In general, it is an effective method especially in reducing microbial load in intact fruits and vegetables. For several reasons such as availability of chlorinated solutions and cost, chlorine disinfections are considered to be good method for application in developing country (Tilahun, 2002).

3.5.3. Biological control

Identification and commercial evaluation of many biological control agents that may be useful in controlling postharvest wastage including fungi, yeasts and bacteria are at a relatively infant state (Wills *et al*., 1998). On the other hand, the ability of natural antibiotic substances to control mould growth are becoming better known. The controlling agents are assumed to be antifungal substances produced by the bacterium that prevents mould development. Another method of biological control is where organism that feed on the pathogen can control disease. Competitions between organisms are a promising area of biological control, with the growth of a nonpathogenic organism preventing the growth of a pathogenic organism (Wills *et al*., 1998).

4. Materials and Methods

4.1. Description of the Experimental Site

The experiment was carried out in the Horticulture Department laboratory of at Wolkite University. Wolkite University is located 168 km away from Addis Abeba to south west direction. It is also located 158 km south of Wolkite town, which is the capital of the Gurage zone. The Wolkite Universsity main campus is located at an altitude of 1300m, about 7.8°-8.5°N latitude and 37.5° 38.7°E longitude. The mean annual temperature ranges from 14 to24°c with an average of 20.5°C. Around 80% of the soil type of the area is heavy vertisol, which is reach in organic matter, athough has less capability to drain readily.The rainfall of is of bimodal pattern, of which about 80% of the rainfall comes in the summer period that extends from June to August. The remainder 20% of the rain comes during the *Belg* period that extends from February to May (GZADD,2011).

4.2. Experimental design and treatments

The experiment was laid out in Complete Randomized Design (CRD) with four replications. The treatments were**:**

(1) Control , (0% $CaCl_2$)

(2) dipping tomato fruits in 2% $CaCl_2$

(3) dipping tomato fruits in 4% $CaCl_2$

(4) dipping tomato fruits in 6% $CaCl_2$.

The experimental treatments was randomized acrtoss the four replications.it was done using the lottery method.The experiment comprised a total of 80 fruits and 16 experimental units (plots).The spacing between respective experimental units (plots) was maintained at 20cm x 20cm across the layered benches of the two laboratory shelves used.

4.3. Experimental procedure

Physiologicaly matured green tomato fruits (with standard Maturity Index I) of the nationally released Galillee variety were purchased from the Minyior commercial vegetable farm near Gubre town (located along the road to Endeber town). They were personally selected from the standing plants on the farm for their maturity in terms of size, maturity stage as well as freedom from any kind of damages. They were then contained in corrugated paper cartons and transported by contact Bujaj to the Hortticlture Laboratory of Wolkite University. fter precooling them for two hours by spreading them across the laboratory benches, in order to stabilize them by removing the field heat, there were washed with clean water, dried through evaporation and polishing by tissue paper, and then graded them further for their uniformity. The best ones were then selected and dipped inside equisized graduating cylinders with the respective four treatment solutions of calcium chloride (0% $CaCl_2$, 2% $CaCl_2$, 4% $CaCl_2$ and 6% $CaCl_2$) and 1000 ml of distilled water for 20 minutes. After drying them by evaporation, five fruits were assigned per experimental unit (plot) and placed inside separate polyethylene bags. They were subsequently stored at room temperature (20 ± 2^oC) while laid out across the layered benches of the two laboratory shelves. Data was collected at weekly intervals starting from from the first day until the fruits become unmarketable. The data collection for all the parameters (DMC, PWL, Firmness, Color Index and Decay, Shelf-life and Marketability assessment) was carried out within the Horticulture Laboratory, except TSS and pH,which was performed at the Food Engineering Laboratory.

4.4. Data collected

Data collection was started right during the first day the experiment was laid out. It was then continued at weekly intervals up until the end of the 63 days long sorage period . By then, over 75% of the fruits had become decayed and the experiment came to an end. Data were collected for the following physicochemical parameters using their respective appropriate procedures.

4.4.1. Physical parameters:

(a) Physiological weight loss of tomato fruits (PWL %)

It was recorded through periodicl weighing of the sample experimental fruits from each experimental unit throughout the experimental period using a precision scale (model: LS200 Sartorius GMBH Gottingen, Germany). It was calculated for the fruits in the respective treatments and expressed as a percentage of the initial weight using the following equation.

$$Weight\,loss(\%) = \frac{Initial\ weight(g) - Final\ weight(g)}{Initial\ weight(g)} \times 100$$ ....Equation. 1

(b) Fruit firmness

It was periodically assessed throughout the 63 days long experimental period using the sensory evaluation technique (procedure) by hand as described by the imaginary hedonic scales of: ***1=*** *"Soft"* **2=** *"Largely soft"****; 3=*** *"Medium"****; 4=*** *"Largely Hard",and* **5=** *"Hard"* depending on the level of firmness of the fruits.

(c) Fruit color index

It was periodically assessed throughout the 63 days long experimental period using the Universal Color Index Chart of Tomato for Maturity and Ripening Stages as decribed: ***Stage 1=*** *"Green mature";* ***Stage 2=*** *"Breakers"* ***; Stage 3=*** *"Turning";* ***Stage 4=*** *"Pink";* ***Stage 5=*** *"Light Red";* ***Stage 6=*** *"Red"* depending on the periodic level of chromatic (color) change of the fruits.

4.4.2. Chemical parameters:

(a) Total soluble solids-TSS (% °Brix)

Sample fruits were blended using a juice blender and TSS of the juice was measured by the refractive index, expressed as °Brix, using a bench top digital Refractometer (Model: SN-003007). The macerated samples were homogenized by adding about 40 ml of distilled water and filtered with cheese cloth. One to two drops of the filtrate was then placed on to the glass prism of the refractometer for reading within the scale. The glass prism was rinsed with distilled water and cleaned with cheese cloth in between the measurement of each of the samples drawn from the experimental units.

(b) Pulp pH

The pH of the sample fruit juice was measured using a bench top digital pH meter (model: CP-505, Poland). The pH meter was periodically calibrated with buffer at pH 4.0 and 7.0 before taking the measurements. pH was expressed as the equilibrium measure of hydrogen ion concentration in the sample fruit juice.

(c) Loss of dry matter content (%)

The loss of dry matter content (%) of the tomato fruits was determined according to the method of AOAC (2005). A 20 gram of the blended fruit juice was periodically taken into a calibrated petridish and placed in the digital oven (model: CP2 + 055F3030D19, UK) at 60°C. Weight of the samples was measured before and after oven drying using an electronic analytical balance (Model: PGW753 ABJ220-4M, Germany). Finally the loss of dry matter content of the fruits was calculated using Eq. 4. (AOAC, 2005).

$$\text{Dry Matter (\%)} = \frac{\text{Final Dry Weight}}{\text{Initial Wet Weight}} \text{x } 100 \qquad \text{Equation 4}$$

4.4.3. Other Associated physical quality parameters:

(a) Fruit decay or rotting (%)

The decay or rotting of the stored tomato fruits was determined using the sensory evaluation procedure using visual observations. Rotten fruits were isolated and the percentage decay was then calculated as a percentage of the total amount of tomato fruits stored using the following formula.

$$\text{Decay (\%)} = \frac{\text{Number of decayed fruits}}{\text{Initial number of all fruits}} * 100$$

(b) Shelf life of fruits (days)

The shelf life of the tomato fruits was estimated as the number of days taken to reach the final red ripe stage (Maturity Index 6) of the fruit just before it enters the senescence (unmarketable) stage The color, firmness as well as the overall appearance of the fruits were rated visually using the sensory evaluation procedures for acceptability by consumers.

(c). **Marketability determination (days)**

The marketability of the stored tomato fruits was periodically assessed throughout the 63 days along experimental period and determined using the sensory evaluation procedure for overall appearance and acceptability by consumers as described by the imaginary hedonic scales of: **1=** ***Marketable/optimum*** *(“Maturity Index 5);* ***2= Moderately marketable*** *(“Maturity Indices 4 & 6)****; 3= Least marketablt*** *(Maturity Index 3), and 4=* ***Unmarketable*** *(“Maturity Indices 1, 2 &> 6).*

4.5. Statistical Data analysis

The data collected for all the parameters were statistically analysed through the Analysis of Variance (ANOVA) by using GLM procedure of GenStat software version 13 The Least Significant Differences (LSD %) test was used to determine the level of significance at 5% levels ($P < 0.05$) of probability using Duncan’s Multiple Range (DMR).

5. Results and Discussion

5.1. Physical Parameters

(a) Physiological Weight Loss (PWL %)

Although the statistical analysis had not shown significant difference *($p \leq 0.05$)* among the fruits treated with all the treatments, PWL was generally increased as the storage period prolonged irrespective of the type of treatments. As shown under Table 1 below, the highest weight loss (20.78%) was recorded on those fruits not treated with calcium chloride (control or 0% $CaCl_2$) while the lowest weight loss (16.91%) was recorded on those fruits treated with the highest concentration (6% $CaCl_2$). This shows that the shelf life tomato fruits can be better extended by treating them with calcium chloride than with tap water only.

Table 1. Physiological weight loss (%) of tomato fruits as affected by different concentrations of calcium chloride ($CaCl_2$) over a period of 63 storage days

Treatment	**PWL (%)**
Control (0%),	20.78[a]
$CaCl_2$ (2%)	19.07[a]
$CaCl_2$ (4%)	18.51[a]
$CaCl_2$ (6%)	16.91[a]
LSD (0.05)	4.443
CV (%)	15.3

Where: *Means indicated by the same letter are non-insignificant 5% level of significance*
($P \leq 0.05$).

(b) Fruit Firmness

As shown under Table 2 below, results on fruit firmness generally revealed a decreasing trend over the 63 days storage period irrespective of treatments (Table 2). Statistically significant difference ($p \leq 0.05$) was observed among the treatments with the highest concentration of calcium chloride (6% $CaCl_2$) maintaining the highest level of firmness (4.0) of tomato fruits throughout the storage period. On the contrary, the highest loss in firmness (3.0) was recorded on those fruits stored without the application of calcium chloride (control or 0% $CaCl_2$).

Table 2. Firmness of tomato fruits as affected by different concentrations of calcium chloride ($CaCl_2$) over a period of 63 storage days

Treatment	**Firmness**
Control (0%),	*3.00*[c]
$CaCl_2$ (2%)	*3.25*[bc]
$CaCl_2$ (4%)	*3.75*[ab]
$CaCl_2$ (6%)	*4.00*[a]
LSD (0.05)	0.5447
CV (%)	10.1

Where: *Means indicated by the same letter are non-insignificant 5% level of significance ($P \leq 0.05$).*

Where: *1= Soft 2= Largely soft; 3= Medium; 4= Largely Hard and 5= Hard*

(c) Fruit Color Index

As stated under Table 3 below, the obvious manifestations of the tomato fruits during the 63 days long storage period in terms of the gradual decline of the green color were clearly observed in the present experiment with different intensities across the different treatments regimes. Statistical analysis also showed significant differences in fruit color-index among the fruits treated with differenct concentrations of calcium chloride ($CaCl_2$). The highest change in fruit color (5.13) was recorded on tomato fruits stored without $CaCl_2$ treament (control of 0% $CaCl_2$) while those treated with the highest concentarion (6% $CaCl_2$) maintained a relatively low change in their color (4.93).

Table 3. Fruit Color_Index of tomato fruits as affected by different concentrations of calcium chloride ($CaCl_2$) over a period of 63 storage days

Treatment	Fruit Color Index
Control (0%),	5.13a
$CaCl_2$ (2%)	5.10^{ab}
$CaCl_2$ (4%)	5.05^{ab}
$CaCl_2$ (6%)	4.93^{b}
LSD (0.05)	0.1807
CV (%)	2.3

Where: *Means indicated by the same letter are non-insignificant 5% level of significance ($P \leq 0.05$).*

Where: *1= Green mature; 2= Breaker; 3=Turning; 4= Pink; 5= Light Red and 6= Red*

5.2. Chemical Parameters

(a) Total Soluble Solids (TSS)

Table 4 below shows that Total Soluble Solids (TSS) content was, gradually but consistently, increased throughout the 63 days long storage period of tomato fruits irrespective of the treatments. The results are generally in agreement with previous findings that the amount of sugars usually increases along with fruit ripening through biosynthesis processes or degradation of polysaccharides (Bassetto et al., 2005). Results also showed that there was a general statistically significant difference ($p \leq 0.05$) among the fruits treated with different concentrations of calcium chloride ($CaCl_2$).

The highest TSS (3.87) was recorded on the fruits stored without $CaCl_2$ treament (control or 0% $CaCl_2$) while those treated with the highest concentarion (6% $CaCl_2$) maintained the lowest level or percentage of TSS (3.54 ^{o}Brix)). As stated by Hernandez et al. (2006), the highest level of TSS (3.87^{o}Brix)) produced by the fruits stored without $CaCl_2$ treament (control or 0% $CaCl_2$) could be an indication of the rapid deterioration in their shelf life as a result of the onset and progress of the climacteric peak caused by the higher rate of respiration .

Table 4. TSS (^{o}Brix) of tomato fruits as affected by different concentrations of calcium chloride $CaCl_2$) over a period of 63 storage days

Treatment	TSS (^{o}Brix)
Control (0%),	3.87a
$CaCl_2$ (2%)	3.80a
$CaCl_2$ (4%)	3.63b
$CaCl_2$ (6%)	3.54b
LSD (0.05)	0.1368
CV (%)	10.3

Where: *Means indicated by the same letter are non-insignificant 5% level of significance ($P \leq 0.05$).*

(b) Fruit pH

It was observed that the pH of tomato fruits generally increased steadily over the 63 days storage period irrespective of treatments. These results were in agreement with the findings reported by Tourky et al. (2014) in that as the storage period or ripening process advances, total acidity (titratable acidity or TA) could increase resulting in an increse in fruit pH. A similar result was also reported by Hernandez et al. (2006) that as the storage period progresses, the evolution of ethylene and respiration rate would increase with a subsequent increse in pulp pH. As stipulated under 5 below, there was as well a statistically significant difference ($p < 0.05$) among the treatments on their effect on the pH of tomato fruits over the storage period. While the fruits treated with the highest concentarion of calcium chloride

(6% $CaCl_2$) maintained the lowest pH level of 4.52, those stored withoutl calcium chloride (control or 0% $CaCl_2$) showed a significant decrease with lowest record of 4.87.

Table 5. pH of tomato fruits as affected by different concentrations of calcium chloride ($CaCl_2$) over a period of 63 storage days

Treatment	**pH**
Control (0%),	4.87a
$CaCl_2$ (2%)	4.77b
$CaCl_2$ (4%)	4.53c
$CaCl_2$ (6%)	4.52c
LSD (0.05)	0.052
CV (%)	0.7

Where: *Means indicated by the same letter are non-insignificant 5% level of significance ($P \leq 0.05$).*

(c) Loss of Dry Matter Content (%)

Fruit dry matter is basically a reverse of the pulp moisture content in that as the later increases with the advance in the storage or ripening period, as a result of carbohydrate breakdown and moisture migration through osmotic pressure from the peel to the pulp, percent dry matter correspondingly decreases (Sarode et al., 2009; Kurmani et al., 2010; Tourky et al., 2014). Likewise, the present study illustrated that the dry matter content of tomato fruits steadily decreased over the 63 days long storage period irrespective of treatments.

Similarly, statistical analysis on the level of loss of dry matter content tomato fruits generally showed significant difference ($p < 0.05$) among the effects of the treatments with different concentarions of calcium chloride($CaCl_2$). While the fruits treated with the highest concentarion of calcium chloride (6% $CaCl_2$) maintained the lowest percentage loss of dry matter content (0.92%), those stored withoutl calcium chloride (control or 0% $CaCl_2$) showed the highest loss of 0.96%.

Table 6. Loss of DMC (%) of tomato fruits as affected by different concentrations of calcium chloride ($CaCl_2$) over a period of 63 storage days

Treatment	**Loss of DMC (%)**
Control (0%),	0.96a
$CaCl_2$ (2%)	0.95a
$CaCl_2$ (4%)	0.93b
$CaCl_2$ (6%)	0.92b
LSD (0.05)	0.01649
CV (%)	1.1

Where: *Means indicated by the same letter are non-insignificant 5% level of significance ($P \leq 0.05$).*

5.3. Other associated physical quality parameters

(a) Shelf-life (days)

As stated under Table 7 below, statistical analysis showed significant difference among the treatments on their effect on shelf-life of tomato fruits. The longest shelf-life (55.75days) was recorded from tomato fruits treated with the highest concentration of calcium chloride (6% $CaCl_2$) while the shortest (38.5 days) was recorded on fruits stored without $CaCl_2$ treatment (control or 0% $CaCl_2$). Tomato fruits are therefore recommended to be treated with the highest concentarion of calcium chloride (6% $CaCl_2$) in order to extend their shelf-life.

Table 7. Shelf_life (day) of tomato fruits as affected by different concentrations of calcium chloride ($CaCl_2$) over a period of 63 storage days

	Shelf_life (day)
Control (0%),	38.50c
$CaCl_2$ (2%)	42.00bc
$CaCl_2$ (4%)	50.75ab
$CaCl_2$ (6%)	55.75a
LSD (0.05)	11.01
CV (%)	13.2

Where: *Means indicated by the same letter are non-insignificant 5% level of significance ($P \leq 0.05$).*

(b) Fruit decay or rotting (%)

As illustrated under Table 8, statistical analysis showed significant difference among the treatments on their effect on fruit decay or rotting over the experimental period. The highest decay (75%) of tomat fruits was recorded on those stored without $CaCl_2$ treatment (control or 0% $CaCl_2$) while the lowest (35%) was recored on those treated with the highest concentarion of calcium chloride (6% $CaCl_2$). Tomato fruits are therefore recommended to be treated with the highest concentration of calcium chloride (6% $CaCl_2$) in order to minimize the level of decay or rotting during storage..

Table 8. Decay or rotting (%) of tomato fruits as affected by different concentrations of calcium chloride ($CaCl_2$) over a period of 63 storage days

Treatment	Decay_%
Control (0%),	75.00a
$CaCl_2$ (2%)	55.00ab
$CaCl_2$ (4%)	50.00ab
$CaCl_2$ (6%)	35.00b
LSD (0.05)	23.95
CV (%)	8.9

Where: *Means indicated by the same letter are non-insignificant 5% level of significance ($P \leq 0.05$).*

(c). **Changes in marketability quality (days)**

As shown in the following table (Table 9) tomato fruits expressed progressive change in their marketable quality over the 63 days long storage period as evaluated using the sensory evaluation procedure for overall appearance and acceptability by consumers, which was described by the imaginary hedonic scales of: 1**= *Marketable/optimum*** *(“Maturity Index 5);* **2= *Moderately marketable*** *(“Maturity Indices 4 & 6)***; 3= *Least marketablt*** *(Maturity Index 3), and 4=* ***Unmarketable*** *(“Maturity Indices 1, 2 &> 6).*

The assessment was carried out alternatively using sensory evaluation parameters (color, firmness, ripening stage and overall appearance). Fruits changed from green mature to full red in terms of color, from firm to very soft in terms of firmness; from green mature to over ripe stage in terms of ripening, and from good into poor in terms of overall appearance over the 63 days storage period.

Table 9. Changes in marketable quality of tomato over the 63 days long storage period

Trteatment		Storage Period (days in Eth.C.)									
		Day1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
		13/7/11	20/7/11	27/7/11	04/8/11	11/8/11	18/8/11	25/8/11	2/9/11	9/9/11	16/9/11
1	Control (0% $CaCl_2$)	4	3.1	2.0	2.0	1.9	2.5	2.8	3.5	4.0	4.0
2	2% $CaCl_2$	4	3.2	1.6	1.8	2.0	2.0	2.4	3.0	3.9	4.0
3	4% $CaCl_2$	4	3.3	2.5	1.8	1.7	2.0	2.0	2.1	3.5	3.6
4	6% $CaCl_2$	4	3.3	2.0	1.7	1.8	2.0	2.0	2.2	3.5	3.8

Where:

1= *Marketable/optimum* *(“Maturity Index 5)*

2= Moderately marketable *(“Maturity Indices 4 & 6)*

3= Least marketablt *(Maturity Index 3), and 4=* ***Unmarketable*** *(“Maturity Indices 1, 2 &> 6)*

6. Summary and Recommendations

- Physiological Weight Loss (PWL %) was generally increased as the storage period prolonged irrespective of the type of treatments. Weight loss of tomato fruits can be better decreased over the storage period under ambient conditions ($23\pm1^{0}C$ and $73\pm1\%$ RH) by treating them with the highest concentration of of calcium chloride (6% $CaCl_2$) when treated (dipped) for 20 minutes. .

- Tomato fruits treated with the highest concentration of of calcium chloride (6% $CaCl_2$) maintained the lowest pH (4.52) at the end of the 63 days storage period.

- Fruits changed from mature green to full red in terms of color, from firm to very soft in terms of firmness; from green mature to over ripe stage in terms of ripening, and from good into poor in terms of overall appearance over the 63 days storage period.

- Considering the above results, it is hereby recommended that the shelf life of tomato fruits can be extended for up to 55.75 days (compared to 38.5 days without $CaCl_2$ treatment or just only tap water treatment) with the highest concentration of of calcium chloride (6% $CaCl_2$) when treated (dipped) for 20 minutes and while stored under ambient conditions (i.e. $23\pm1^{0}C$ and $73\pm1\%$ RH).

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8. Annexes

Annex Table 1. Analysis of Variance (ANOVA) for Total Soluble Solids (TSS).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	0.280719	0.093573	11.86	<.001
Residual	12	0.094675	0.007890		
Total	15	0.375394			

Annex Table 2. Analysis of Variance (ANOVA) for pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	0.380169	0.126723	112.43	<.001
Residual	12	0.013525	0.001127		
Total	15	0.393694			

Annex Table 3. Analysis of Variance (ANOVA) for PWL (%)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	30.693	10.231	1.23	0.341
Residual	12	99.787	8.316		
Total	15	130.480			

Annex Table 4. Analysis of Variance (ANOVA) for Firmness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	2.5000	0.8333	6.67	0.007
Residual	12	1.5000	0.1250		
Total	15	4.0000			

Annex Table 5. Analysis of Variance (ANOVA) for DML (%)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	0.0029687	0.0009896	8.64	0.003
Residual	12	0.0013750	0.0001146		
Total	15	0.0043437			

Annex Table 6. Analysis of Variance (ANOVA) for Color Index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	0.09500	0.03167	2.30	0.129
Residual	12	0.16500	0.01375		
Total	15	0.26000			

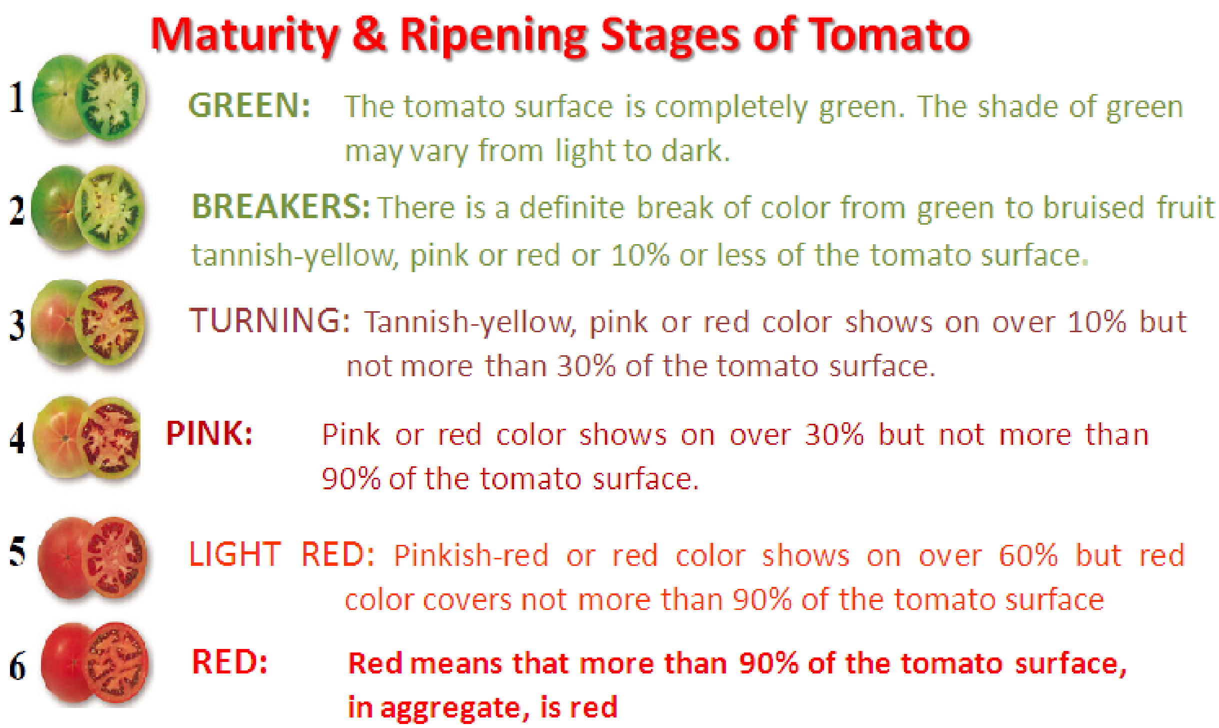
Annex Table 7. Analysis of Variance (ANOVA) for Shelf life (day)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	906.50	302.17	5.92	0.010
Residual	12	612.50	51.04		
Total	15	1519.00			

Annex Table 8. Analysis of Variance (ANOVA) for Decay or Rotting (%)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	3275.0	1091.7	4.52	0.024
Residual	12	2900.0	241.7		
Total	15	6175.0			

Annex Table 9. Universal Color Index Chart of Tomato for Maturity and Ripening Stages



Annex Plate 1: Field harvesting

Annex Plate 2: Field packaging

Annex Plate 3: Precooling
(removing field heat & stabilizing)

Annex Plate 4: Grading fruits ***(for experimentation)***

Annex Plate 5: Washing & drying graded fruits

Annex Plate 6: Randomization ***(Lottery method)*** **& Treatment**

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annex plate7:$CaCl_2$

Annex Plate 7: Fresh weight & other 1st date data collection

Annex Plate 8: Subsequent dates PWL (%) measurement

Annex Plate 9: Slicing & juicing for DM, TSS & pH analysis

Annex Plate 10: Digital Refractometer & pH meter
(used for TSS & pH measurement)

Annex Plate 11: Layout of experimental units

Annex Plate 12: Assessment of postharvest decay (%)