POSTHARVEST QUALITY OF FRESH TOMATOES AS AFFECTED BY TWO STORAGE TEMPERATURES AND DIFFERENT SANITIZERS

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Horticulture)

Department of Horticulture
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The thesis attached hereto, entitled **"Postharvest quality of fresh tomatoes as affected by two storage temperatures and different sanitizers"** was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and the board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Horticulture).**

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DECLARATION OF ORIGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS,

U MOE MYINT TUN AND DAW KHAING PA PA CHIT

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ABSTRACT

The experiment was carried out to assess the postharvest quality of fresh tomatoes as affected by two storage temperatures and different sanitizers, at the Department of Horticulture, Yezin Agricultural University (YAU) in rainy season 2017 and winter season in 2018. This study was laid out into factorial arrangement in RCB design with four replications. The tested tomato varity was “Kyauk Mae Gaung Sein” harvested at pink stage. The factor (A) was two storage temperatures: ambient (rainy season 36°C ± 2, winter season 29°C ± 2) and cold (13 ℃). The factor (B) was different sanitizers: water, clorox (sodium hypochlorite), common salt (sodium chloride), vinegar and control. The data on fruit weight loss (g), decay fruit percent, firmness (score), peel color changes (score), pH, titratable acidity (%), total soluble solid content (Brix %) were collected at three-day intervals for about one month and the shelf-life was determined at the end of storage period based on visual quality rating. In both seasons, significantly lower weight loss, decay fruit percent and longer shelf-life were observed in the fruits stored in cold room than those under ambient conditions. Tomato fruits stored in cold room showed firmer fruits and slower rate of color development than those under ambient condition. However, cold-stored tomatoes were found to have lower total soluable solids (Brix %) and titratable acidity (TA %) than the ambient condition. Among different sanitizers, longer shelf-life (24 days) and higher remaining weight (486.27g) were observed in water and vinegar-treated fruits than the others in rainy season. In winter season, vinegar-treated fruits gave the longest shelf-life (30 days) and the value was five days longer than control fruits. Vinegar could also maintain fruit firmness and acidity, and reduce decay fruits % and weight loss. It could retain the highest remaining weight (473.50g) among all sanitizers used at the end of the storage periods. No interaction effect was observed between storage temperature and sanitizer treatments in this study. Therefore, this study highlighted that tomato fruits should be stored in cold room (13̊ C) to get maximum shelf-life in both seasons and vinegar should be used as a sanitizer to reduce weight loss and retain good quality of tomato in winter season.

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CHAPTER I
INTRODUCTION

Tomato (*Solanum lycopersicum* L.) which belongs to the family Solanaceae is a herbaceous plant native to central, South and Southern North America from Mexico to Argentina. It is the second world's largest vegetable crop after potato and grown for its edible fruits. It is the second leading vegetable crop worldwide with a production of over 4.7 million ha with the yield of about 177 million metric ton (FAOSTAT 2016). In Asia, the total tomato production was about 106 million metric ton (FAOSTAT 2016).

In Myanmar, tomato is also one of the profitable crops for growers. The main production areas of tomato are Mandalay, Magway, Sagaing, Bago Regions and Southern Shan State. The total sown area in Myanmar was 113771 ha with average yield of 11.64 mt/ha in 2016 (MAS 2016). Tomatoes are especially important for the human diet because of their content of vitamin C, vitamin A, lycopene and phenolic compounds. Moreover, results from the epidemiological studies have shown that tomato and its products may have a positive effect against various forms of cancer, especially prostate cancer and cardiovascular diseases (Ellinger et al. 2006).

However, tomatoes rapidly deteriorate after ripening, and a large portion of the valuable products are lost after harvest. In tropical countries, a loss of 20-50% has been reported for fresh tomatoes during harvest, transport and consumption process (Pila et al. 2010). Postharvest losses of tomato in Myanmar are about 30 – 40% (Hla 2005). Major causes of losses are high perishability, microbial contamination, improper storage temperature, loss of water content during storage and careless handling operations. Therefore, it is needed to reduce those postharvest losses to a certain extent. In order to reduce these losses, fresh produces are harvested at green immature stage. However, early harvested fresh produce receives criticisms about poor taste, green and hard fruit (Kader 2002).

The proper use of sanitizers in postharvest wash can help prevent both postharvest diseases and food borne illness. Sanitation after harvest is critically important for all fresh products, where it can reduce spoilage losses by 50% or more (Sargent et al. 2000). Sanitizers are also widely employed to minimize contamination of produce with pathogens of human health concern (Gómez-López et al. 2013). The most popular sanitizers are chlorine (hypochlorite), chlorine dioxide, ozone, ethanol, hydrogen peroxide, organic acids and electrolyzed water (Suslow 2000).

Disinfection of tomatoes with sodium hypochlorite (NaOCl) reduced subsequent microbial spoilage (Smid et al. 1996). The antimicrobial effects of sodium chloride (NaCl) as a low toxicity agent have been indicated by several studies and it can be used as a surface disinfection for fresh fruits and vegetables (Cliver 2003). Vinegar (acetic acid) was also used as an antimicrobial preservative to safe the environment (El-Katatny et al. 2012).

Postharvest losses of tomatoes are influenced by a great number of factors that include the internal or commodity factors and the external or environmental factors. Among the environmental factors, temperature is the most important one and it influences the rate of all metabolic processes, including respiration and transpiration (Sunil 2016). Current postharvest problems are mainly concerned with shelf-life. Temperature management is the most effective tool for extending the storage life of fresh horticultural products. Tomatoes can be stored in cold rooms successfully for several weeks, however recommended storage temperatures differ according to the fruit maturation stage and variety. Improper temperature management is the primary cause of many postharvest decays. Thus, it is necessary to determine the proper storage temperature for maximum shelf-life of a certain tomato variety. Therefore, the present study was undertaken with the following objectives:

1. To determine the suitable storage temperature for longer shelf life of fresh tomato in good quality and
2. To investigate the most effective sanitizer on reducing spoilage of tomato fruits during storage.

CHAPTER II
LITERATURE REVIEW

2.1 An Overview on Tomato Production

Tomato (*Solanum lycopersicum* L.) is the most common vegetable in the world and has the highest economic value. In addition, it is one of the short-duration crops which give high yield. The nutritional and economic importance of tomato has led to its global production. By weight, tomatoes rank second only to potatoes in global production of all horticultural produce (Tan et al. 2010). Tomatoes production can serve as a source of income for most rural and peri urban producers in most developing countries of the world (Arah et al. 2015). Moreover, tomatoes were used as fresh and also in processed forms in both industrialized and developing countries. Besides the health benefits derived from tomatoes and tomato-based foods, the crop can serve as a source of income for farmers as a result of its numerous uses. The tomato industry can increase the foreign export earnings of many countries (Anang et al. 2013).

The worldwide production of tomato totaled 170.8 million tons. China, the leading producer of tomatoes, accounted for 31% of the total production. India and the United States followed with the second and third highest production of tomatoes in the world. In the European Union, tomatoes accounted for 23% of the total output of fresh vegetables in 2014 (FAOSTAT 2014).

In Myanmar, tomato is generally grown in winter season, planting in October/November and harvesting from January to March (DAP 2011). However, in Shan State, tomato could be grown year round. The total sown area in Myanmar was 113771 ha with average yield of 11.64 mt/ha in 2016 (MAS 2016). The main production areas of tomato are Mandalay, Magway, Sagaing, Bago regions and Southern Shan State. Inle Lake is the main production source and also a high production area of tomato in Shane sate (MAS 2004). Tomatoes have the tendency of improving the lives of small scale rural farmers in Myanmar.

Tomatoes are considered as an important cash generating crop for smallholders and medium-scale commercial farmers providing employment opportunity in the production and processing industries (Naika et al. 2005). In addition to common consumption in daily diets, tomatoes are a major source of antioxidants and vital nutrients. Awas et al. (2010) indicated that the high nutritional value and potential health benefits of tomato have drawn an increased interest towards tomato-based products among consumers. They make significant contributions to human nutrition throughout the world (Toor et al. 2006).

2.2 Postharvest Losses of Tomato

The postharvest losses of vegetables are higher than any other cereal crops. Such losses are attributed to the perishable nature of vegetables, tomato is one of the vegetables which causes deterioration more quickly after ripening. Postharvest losses in tomatoes can be either quantitative or qualitative. In tropical countries, a loss of 20-50% has been reported for fresh tomatoes during harvest, transport and consumption process (Pila et al. 2010). Zaldivar (1991) cited several reports, tomato provide loss figures of 25% or 28-42% worldwide, and 15-60% or 15-50% in less industrialized counties. Postharvest losses of tomato in Myanmar are about 30-40 % (Hla 2005)

Post-harvest produce losses include poor pre-harvest measures, adoption of poor production techniques (varieties with low shelf-life, imbalance use of nutrients, insect pest and disease infestation and abiotic stresses), non-application of pre-harvest recommended treatments/practices, harvesting at improper stage and improper care at harvest and post-harvest problems, non-removal of field heat, dumping produce, moisture condensation causing pathogen infestation, packaging in bulk without sorting and grading of produce, improper transportation and storage, and distant and time consuming market distribution. These losses bring low return to growers, processors and traders and country also suffers in terms of foreign exchange earning (Kader 1992).

The main reasons of losses are the physical damage, bad handling and inability to sell in time. Losses from producer to the consumer may be as high as 50% because of the lack of infrastructure and/or poor handling and marketing know-how (Kader 1992). Training is an essential step to reduce postharvest losses and improve fresh product quality. Kader (2005) mentioned important strategies to reduce postharvest losses in developing countries.

Post-harvest losses occur in every country, but the magnitude and major causes of losses and the effective remedial methods differ greatly from one country to another, one season or even one day to another. Post-harvest losses are higher in less industrialized counties, this generalization may not be true and higher losses may occur in developing countries for lack of good facilities and technologies. However, these losses may be lower in less urbanized regions, where the products need to be transported a shorter distance to market, and there is a shorter time lag period between harvesting and consumption (Bourne 1986).

2.3 Quality Parameters of Tomato Fruit

2.3.1 Peel color of fruit

The measurement of color is one of the quality factors of fresh tomatoes for consumer preference and it is most practical and successful technique for non-destructive quality evaluation. Classifications of color and ripening stages have been done for years in many developed countries. The skin color of fruits such as tomato has a strong effect on consumer acceptability of product (Ali et al. 2004). Important color changes occur at various stages of tomato development in terms of chlorophyll (green color), β-carotene (orange color) and lycopene (red color) contents (Bathgate et al. 1985).

Changes in fruit color typically involve the destruction of chlorophyll to reveal other pigments already present and may also involve the synthesis of additional pigments (Sunil 2016). The most visible changes are associated with chlorophyll loss and gradual accumulation of lycopene in tomato. The result of red color is degrading chlorophyll as well as synthesis of lycopene and other carotenoids. Formation of lycopene was dependent upon the presence of O_2. Its formation was inhibited by low O_2 atmosphere storage (Ali and Thompson 1998). Variation in color readings between maximum and minimum values increase during ripening of tomatoes and is most variable at the pink stage of maturity (Ali et al. 2004).

2.3.2 Firmness of fruit

Fruit firmness is also an important quality decisive factor in tomatoes because it is associated with good eating quality and longer postharvest life. Skin texture and color are the two most important quality parameters for consumers and buyers of fresh tomatoes (Tijskens and Polderdijk 1994). Flesh firmness and strength of the skin influence the tomato texture (Kader et al. 1978) and degree of firmness is an indicator of fruit quality (Burton 1982). Texture of over ripe and damaged products will be softer than optimum mature products. Thus firmness can be used as a criterion for quality of fruits (Ali et al. 2004). The loss of freshness and softening of the tomato tissue is the result of turgor pressure loss and polysaccharides degradation in tomato fruit pericarp (Ealing 1994 and Femenia et al. 1998). Initially gradual softening of the tissues and subsequently taste deterioration are the characteristics of external symptoms which are due to respiratory rate and polysaccharide changes (Chiesa et al. 1998, and Van der Valk and Donkers 1994).

Haiking and Baerdemaker (1990) conducted an experiment in USA, with three distinct mature tomato fruits and stored for 12 days at 20°C. They observed that best firmness performances were at green mature stage followed by pink and initial red stage. In another experiment in Turkey, Kaynas and Surmeli (1995) reported that tomato fruits firmness decrease during storage.

2.3.3 pH of fruit

Citric and malic acids are organic acids that contribute most to the typical taste of tomato fruit. Other acids such as acetic, formic, trans-aconitic, lactic, fumaric, galacturonic, and a-oxo acids have been detected. Acid content was found increases to a maximum value and then decreases, when fruit ripens from mature green to red (Winsor et al. 1962 and Dalal et al. 1965).Winsor et al. (1962) found that maximum pH value can be recorded at the pink stage of tomato fruits.

The pH of the fruits with respect to harvesting methods and calcium chloride treatments are studied. The pH of the fruit juice harvested without retaining the stalk showed slightly higher pH compared to those harvested with stalk. There is no apparent effect of calcium treatment and it was recorded maximum (4.067) in control fruit and that of minimum (4.017) to 0.75% calcium chloride treated fruit (Bhattarai and Gautam 2006).

2.3.4 The ratio of total soluble solids (TSS) and titratable acidity (TA)

The ratio TSS/TA is an important factor for quality parameters of tomato fruits, since it is known that sweetness and sourness are important criteria for tomato flavor (Stevens et al. 1979). The major sugar substances that contribute to sweetness are glucose and fructose that play a major role in taste (Stevens et al. 1977). In general, the values commonly obtained for soluble solids of different varieties of tomato fruit range from 4 to 6 Brix % (Cramer et al. 2001). Sinaga (1986) reported that sugar content increased during maturation from the green mature to the red ripen stage. Salunkhe et al. (1974) reported that soluble solids content increases with fruit maturity through biosynthesis process or degradation of polysaccharides. Sugar content varied with the stage of harvesting. Castro et al. (2005) reported similar relationship in the changes of titratable acidity of tomatoes during ripening and storage where overall acidity slightly increased soon after harvest and then tended to decrease throughout the storage period. Dalal et al. (1965) reported that tomato fruits contained generally about 0.31% acidity (as citric acid) at ambient condition. Saimbhi et al. (1987) reported that a wide range variation in acid content of different tomato cultivars.

The increase of the maturity index values at earlier stages of ripeness denotes a lower TSS content in relation to a higher TA value at earlier stages. Deltsidis et al. (2015) also found that the TSS and TA of tomato under cold storage (5℃) decreased slower than 20℃ in storage. In India, Das and Medhi (1996) studied physico-chemical changes in pineapple fruits (cv. Kew) during storage and observed that the TSS and acidity ratio increased gradually during the storage period in fruits.

2.4 Factors Affecting Tomato Fruit Quality

2.4.1 Internal or commodity factors

Fruits and fruit vegetables are classified into two main classes based on their respiration rate and pattern during maturation and ripening, viz. climacteric and non-climacteric. Climacteric fruits show an increase in CO_2 production during ripening and non-climacteric fruits show no change in CO_2 production during ripening (Kader 2002). Tomatoes are climacteric fruits and have a moderate respiration rate varying between 10-20 mg of CO_2 kg^{-1} h^{-1}. During the climacteric rise of respiration, tomato fruits soften, the yellow color intensifies (loss of chlorophyll and increase in carotenoids) and fruit aroma (volatiles) increases. The peak of respiration rate usually represents the time at which tomatoes are considered ripe for consumption. Afterwards, respiration gradually decreases as the fruit senesces. Respiration rate is investigating the physiology of fresh commodities. It has been reported that the storage life and quality of commodities is inversely proportional to the rate of respiration (Valero and Serrano 2010) which is attributed to the fact that respiration supplies the energy required to drive other metabolic processes that are related to quality parameters such as flavor, firmness, sugar content, aroma, etc.

Tomatoes are one of several large fleshy fruits that have extensive intercellular air spaces interconnected among the loosely bound ceils. In apples, pears, and citrus the air spaces are connected with stomata in the epidermis for exchange of water vapor and gasses such as oxygen and carbon dioxide. Tomatoes have a waxy cuticle on the surface. The cuticle is typically resistant to the passage of water or water vapor and plays an essential role in restricting water loss by evaporation and maintaining high water content within the tissue. However, mature tomatoes are characterized by a relatively thick external wall with a heavily cutinized epidermis that has no stomatal openings. The exchange of water and gases in tomatoes occurs almost entirely at the stem scar (Roberts et al. 1993). Bartz (1982) stated that tomato are submerged in water of a lower temperature, the internal air contracts and water is drawn into the fruit through the stem scar or any surface not covered by cuticle. The tomato skin is an effective barrier against most diseases as long as it remains unbroken.

Transpiration is one of the factors affecting in postharvest quality of fresh produce. Transpiration is a mechanism in which water is lost due to differences in vapor pressure of water in the atmosphere and the transpiring surface. This results in shrinkage, weight loss and changes in texture (softening) and appearance (fading) that may lead to loss of fruit quality (Gharezi et al. 2012).

Ethylene is a fruit and vegetable regulatory hormone (C_2H_2) of growth, development and senescence phase (Roberts et al. 1993). It is also important in postharvest handling of fruits and vegetables, having a wide range of effects that lead to quality loss (Saltveit 1999). The ethylene production rate usually increases with ripeness, injury incidence, disease and temperature increase (Yahia and Brecht 2012). Climacteric commodities increase the synthesis of ethylene during the final stage and also accelerate ripening and senescence. It also steps up the onset of respiration rate in climacteric plants and reduces shelf-life (Barry et al. 2005).

2.4.2 External or environmental factors

Postharvest handling temperature has a major effect on tomato quality. Temperature influences the rate of all metabolic processes, including respiration. In general, the rate of ripening and changes in the color of tomatoes increase as storage temperature increases. The activity of enzymes in fruit and vegetables declines at temperature above 30°C, but temperature at which specific enzymes becomes inactive varies. Continuous exposure of some climacteric fruits to a temperature of about 30°C causes the flesh to ripen, but the fruits fails to color normally, for examples, lycopene (red pigment) accumulation in tomato is inhibited. When produce is held above 35℃, metabolism becomes abnormal and results in a breakdown of membrane integrity and structure, with disruption of cellular organization and rapid deterioration of the produce. The changes are often characterized by a general loss of pigments and the tissues may develop a watery or translucent appearance. Such a condition in tomato is referred to as 'boiled' (Sunil 2016).

Relative humidity (RH) is the second most important factor for modulating changes in physiology and the quality of fruits and vegetables in postharvest systems (Sunil 2016). It can influence water loss, decay development, incidence of some physiological disorders, and uniformity of fruit ripening. Tomato fruits are very high in water content and susceptible to shrinkage after harvest. Fruit shrivelling may become evident with any small percentage of moisture loss. The optimal values of relative humidity for mature green tomatoes are within the range of 85-95 % (v/v) but 90-95 % (v/v) for firmer ripe fruits (Hong 1999). Below the optimal range, evapotranspiration increases resulting in shrivelled fruits. Storage of tomato fruits at a lower relative humidity can result in shrivelling. Addition of moisture (wetting fruits) in lower relative humidity storage can reduce weight loss and prevent fruit from shrivelling. Meanwhile, completely saturated atmospheres of 100% relative humidity should be avoided, as moisture condensation on the fruit surfaces may encourage mould and fungal development (Isaac et al. 2015).

Abiotic stresses may be possible include due to preharvest factor and postharvest handling and storage. It is significant determinants of quality and nutritional value of fruits and vegetables during harvest, handling, storage and distribution to consumer (Peter and Hodges 2011).

2.5 Methods to Extend the Postharvest Life of Tomato

2.5.1 Heat treatment of tomato

Postharvest heat treatments using hot air and heated water have been reported to reduce chilling injuries in fruits like mangoes, oranges, zucchini, and tomatoes (Rodriguez et al. 2001). Hot water treatment is considered to be better than air treatment in reducing chilling injury (Lurie and Klain 1997). According to Zhang et al. (2005), heat treatments that increase chilling tolerance are thought to be related to induced synthesis and accumulation of specific heat shock proteins (HSPs). Krishnan et al. (1989) reported that these proteins can cause thermotolerance on the tissue in which they are formed and hence subsequent exposure to chilling temperature does not cause damage. The study of Zamora et al. (2005) indicated that cherry tomato fruits exposed to hot air at 34°C for 24 hrs prior to storage at 10°C for up to 30 days showed the least loss in antioxidant content and fruit color developed adequately. In addition, Tadesse et al. (2015) noted that hot water treatment of tomato fruit in 40 and 50°C for 20 minutes. can maintain quality of tomato fruits by enhancing physical and quality attributes.

2.5.2 1-Methylcyclopropene (1-MCP)

1-methylcyclopropene (1-MCP) has been used to suppress the action of ethylene in many fruits and vegetables (Cliff et al. 2009). The compound 1-methylcyclopropene **(**1-MCP) is an odorless gas that has a physical similarity to ethylene allowing it to bind to the ethylene receptors in fruits, thus inhibiting the normal action of ethylene and prolonging the storage life of fruits. It is a structural analogue of ethylene and irreversibly binds to the ethylene receptors in the plant, thus preventing ethylene-initiated ripening (Blankenship and Dole 2003).

The use of 1-MCP has been shown to slow down many of the metabolic activities associated with the ripening process such as color change, cell wall breakdown, weight loss, reduce decay and respiration rates. In tomato, 1 µl L^{-1} was required to block ethylene action and to reduce the weight loss during storage (Wrzodak and Gajewski 2015).

2.5.3 Calcium chloride ($CaCl_2$)

Calcium chloride ($CaCl_2$) conserves the qualities of fruits, prevents physiological disorders, reduces the rate of respiration, lessens the solubilization of pectin substances, maintains the firmness and slows down the ripening process (Ishaq et al. 2009). Lester and Grusak (2004) also noted that both pre- and postharvest calcium application delayed senescence in many fruits without any negative effect on consumer acceptability.

In tomatoes, calcium chloride treatment is vital for maintaining quality of fruits by reducing the physiological disorders, delayed ripening process and color increasing the fruit firmness and slowed down ethylene production, thereby extending shelf life by 92% prolonging the shelf life (Abbasi et al. 2013). Bhattarai and Gautam (2006) also reported a reduction of physiological weight loss in tomatoes from 19% to 17% by using 0.25% $CaCl_2$ application for 10 days storage.

2.5.4 Sanitizers

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. Water is not a constraint, the use of sanitizer in water either for washing or for cooling can reduce both postharvest and food-borne diseases in fruits and vegetables. The most commonly-used sanitizers are acetic acid, ammonium sanitizers, chlorine, hydrogen peroxide, ozone, peroxacetic acid and sodium chloride. Genanew (2013) stated that sodium hypochlorite solution has been used to sterilize tomato fruits in order to reduce the incidence of fungal infection before any postharvest treatment was applied. Dipping of tomato fruits in thiabendazole solution reduced the microbial load on the fruits (Batu and Thompson 1998).

Fruits and vegetables are usually treated with chlorinated water after washing to reduce the microbial load prior to packaging. Workneh et al. 2010 indicated that dipping in analyte water for disinfection of tomatoes not only reduced the microbial loads on the fruits but also maintained superior quality of tomatoes during storage. Acetic acid or vinegar vapor was effective in preventing conidia of brown rot (*Monilinia fructicola*), grey mould (*Botrytis cinerea*) and blue mould (*Penicillium italicum*) from germinating and causing decay of stone fruits, strawberries and apples (Sholberg et al. 2000). Disinfection of tomatoes with sodium hypochlorite before packaging greatly reduced subsequent microbial spoilage (Smid et al. 1996).

2.5.5 Modified atmosphere packing (MAP)

Modified atmosphere packaging (MAP) refers to a packaging technique of using specialized materials in packaging products in a predetermined composition of gases which are mainly oxygen (O_2) and carbon dioxide (CO_2) after which there is no active effort of modifying the storage space (Beckles 2012). The packaging materials used in MAP allow for diffusion of gases through them until a stable equilibrium is reached between the external gases and those inside the package (Phillips 1996). The most commonly used MAP materials are polyethylene terephthalate (PET), low density polyethylene (LDP), high density polyethylene (HDP), polyvinyl chloride (PVC), polypropylene (Dewild et al. 2003), polystyrene (Sandhya 2010), and some chemically modified derivatives (Beckles 2012). The benefit of using MAP is not only in providing a modified atmosphere to control ripening (Kader and Watkins 2000), but also in reducing water loss in stored products (Cantwell et al. 2009), reducing mechanical injuries, and enhancing better hygiene which reduces the spread of food-borne diseases (Kader and Watkins 2000).

MAP creates water saturated or near-saturated atmosphere (high relative humidity) around the fruit which reduces water loss and shrinkage (Batu and Thompson 1998). Water loss and subsequent shriveling of tomatoes in tropical regions are one of the causes of their deterioration. The use of MAP by tomatoes handlers in developing countries will therefore prevent or reduce the problem of water loss in harvested tomatoes. But tomato handlers must be trained in the proper use of MAP for tomatoes to avoid moisture condensation which will result in fruit deterioration.

Sabir and Agar (2011) investigated the effects of 1-methylcyclopropene (1-MCP), modified atmosphere packaging (MAP) and their combination of storage and quality maintenance of tomatoes harvested at two maturity stages. The results depicted that 1-MCP treatment with or without MAP led to significant delay in the fruit ripening as indicated by skin color, lycopene and TA increase in both ripening stages.

2.5.6 Controlled atmosphere storage (CA)

CA also delayed the qualitative loss as signified by lycopene synthesis as well as sugar and chlorophyll degradation (Goodenough and Thomas, 1980; Nakhasi et al. 1991). The optimum combination of CO_2 and O_2 (3% O_2 + 2% CO_2) led to good quality of the product (Wills et al. 1998). Storage with 3% O_2 + 97% N_2 enhanced the postharvest-life of mature-green tomatoes by 6 weeks at 13°C (55.4°F) with no off-flavors (Parsons et al. 1970). CA also curtailed undesirable symptoms consequent to mechanical injuries due to internal bruising etc. (Kader 1986 and Moretti et al. 1999).

2.5.7 Cold storage

Storage at low temperature is the main method for reducing deterioration of harvested fruits and vegetables. The importance of cold storage in decay suppression is so great that all other control methods are frequently considered as supplements to refrigeration (Ecker 1995). Low temperature affects both the host and the pathogen simultaneously. They prevent moisture loss from the host tissues and consequent shriveling; they retard metabolic activity and delay physiological changes that lead to ripening and senescence (Sunil 2016).

Since fruits and vegetables become generally more susceptible to pathogens as they mature and approach senescence, the retardation in the physiological activity of the host is accompanied by a delay in decay development after harvest. As with the host, the metabolic activity of the pathogen is also directly influenced by the environmental temperature, and both its growth ability and enzymatic activity can be greatly retarded by low temperatures. Low temperatures can thus delay postharvest disease development in two ways: (a) indirectly, by inhibition of ripening and senescence of the host and extension of the period during which it maintains its resistance to disease; and (b) directly, by inhibition of pathogen development by subjecting it to a temperature unfavorable for its growth (Sunil 2016).

2.6 Traditional Methods Used for Tomato Storage in Myanmar

Generally, the tomato growers in Myanmar do not have specificstorage facilities. In handling of tomato, only traditional methods are employed. Some traditional methods are keeping the produce in a shaded area, burrowing the ground and putting the fruits in the pit, storing the fruits in clay pot and covering it with sand back or collecting immediately by collectors and wholesalers. Another method is storage in wooden crates lining with papers and spreading the ash evenly at the bottom of the crates about 4 cm thickness. The tomatoes are placed upside down (stem end facing down) in one layer and pour another thin layer of ash on the fruits. Putting tomatoes and ash is continued alternately until the container is full. Then, the container is covered and kept in a cool dry place. Although the skin will wrinkle visually, the pulp inside will remain juicy (U Thein Tun, Nwe Yite village, Takkone)

Special packaging of tomato is not usually practiced. All the farmers transported tomatoes to local market using indigenous materials such as banana leaf, bamboo basket and wooden box (Kyi et al. 2013). Handling practices during storage for tomato at the retailer sites are spreading out the fruits in a thin layer, putting them in bamboo baskets or plastic bags and covering the fruits with wet cloth (Hnin 2014). Polyethylene bag, styrofoam tray with cellophane wrappers are currently used for tomato in supermarket (Kyi et al. 2013).

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site and Periods

Two experiments were conducted at Laboratory of Department of Horticulture in Yezin Agricultural University, Nay Pyi Taw, Myanmar. Experiment I was carried out from 8 August to 11 September, 2017 (rainy season) and Experiment II was conducted from 10 January to 15 February, 2018 (winter season).

3.2 Procurement of Experimental Materials

The popular tomato variety in Pyinmana area, Kyauk Mae Gaung Sein, was used as tested cultivar in this study and the fruits were harvested at pink stage from the field of some selected growers in Tatkone township. Freshly harvested tomato fruits from the plants which were grown in rainy season were used for the first experiment and those planted in winter season, for the second experiment. The fruits which were more or less uniform in size (35-40 mm in diameter), shape, color and free from mechanical damages were selected visually for both experiments.

3.3 Experimental Designs and Treatments

For both experiments, factorial arrangements in randomized complete blocked (RCB) design with four replications was used. The treatments were:

Factor A: Storage temperatures

- Ambient condition (36°C ± 2 in rainy season and 29°C ± 2 in winter season)
- Cold storage (13 ˚C)

Factor B: Different sanitizers

- Control
- Water (tap water for 5 mins)
- Clorox (0.05 % v/v for 10 mins)
- Common salt (0.85 % v/v for 30mins)
- Vinegar (5 % v/v for 5 mins)

3.4 Experimental Procedure

For both experiments, selected fruits were treated with different sanitizers according to the treatments as mentioned above. After the application of treatment, the fruits were air-dried on a bamboo tray for approximately 15 minutes at ambient condition. Then, the fruits were put in plastic baskets and stored under two conditions, ambient and cold rooms for about one month.

3.5 Data Collection

For each treatment 1.5 kg of selected fruits were used. Of these fruits, 0.75 kg were used for non-destructive samples to assess the data on color development (score), firmness (score), weight loss (g), shelf life (days) and decay percent. And the remaining fruits were used as destructive samples for the data such as total soluble solids (Brix %), titratable acidity (TA %), and pH of fruit. Three sample fruits from each experimental unit were used for destructive analysis at one time. The data were collected at three-day intervals from the beginning to the end of the experiment. The detail procedure for each data collection were described as follows.

Total soluble solids (Brix %). Total soluble solid (TSS) content of tomato pulp was estimated using a pocket refractometer (PAL -1). A drop of tomato juice squeezed from the fruit pulp was placed on the prism of the refractometer and TSS was recorded as Brix% from direct reading of the instrument.

Fruits pH. The pH content of tomato fruit pulp was determined by using portable pH meter by squeezing the juice from the pulp of tomato fruit.

Titratable acidity (TA %). For the determination of titratable acidity, 5 ml of extracted tomato juice were mixed with 40 ml of distilled water. In the presence of phenolphthalein as an indicator, the mixture was titrated by adding 0.1 N NaOH until the break of light pink color was observed. Titratable acidity was calculated by the following formula (P.H.T.R.C 2009).

$$\%TA = \frac{(VN)_{NaOH} \times \text{Meq.Wt.predominant acid} \times 100\%}{\text{Wt. equivalent of aliquot in g}}$$

Where: V = volume in mL of NaOH used

N = concentration, in normality, of NaOH used

Meq. Wt. = milliequivalent weight in g/milliequivalent

For juice analysis,

$$\text{Wt. equiv. aliquot} = \frac{\text{Fresh wt. of sample in g}}{V_T \text{juice}} \times V_{aliquot}$$

Where: V_T = total volume of juice obtained from sample

Weight loss. Tomato fruits used as non-destructive sample for each experimental unit were weighed initially and recorded at three-day interval by using electronic balance.

Color and firmness. The changes in color of tomato was determined using a numerical rating scale and firmness of tomato fruit was determined subjectively with the help of fingers pressure to measure changes in firmness during the storage period. The firmness of fruits was estimated by score (Table 3.1) (P.H.T.R.C 2009).

Shelf-life (days). The shelf-life of tomato fruits was determined when the fruits reached unmarketable stage by visual quality rating (VQR). The shelf-life was counted the number of day between the starting date of experiment and the date at which VQR stage 3 was reached (Table 3.1) (P.H.T.R.C 2009).

3.6 Data Analysis

The data obtained from the study were analyzed using Stastistix 8 statistical software. Mean separation was performed by using least significance difference (LSD) at ($P \leq 0.05$) level.

Table 3.1 Scores and Description for some quality parameters of tomato fruits

Parameters	Score and Description
Color	1 - Green (completely green but mature) 2 - Breaker (definite break in color but not more than 10% of fruit surface) 3 - Turning (more green than red) 4 - Pink (more red than green) 5 - Light red (trace of green) 6 - Red (Fully red)
Firmness	4 - hard (field fresh) 3 - slightly soft 2 - moderately soft 1 - completely soft
Visual Quality Rating (VQR)	6 - excellent, field fresh 5 - good, defects minor 4 - fair, defects moderate 3 - poor, defects serious, limit of saleability 2 - limit of edibility 1 - non-edible under usual conditions

Harvested Tomato fruits (pink stage)

Different sanitizers

1. Control
2. Water (tap water for 5 mins)
3. Clorox (0.05 % v/v for 10 mins)
4. Common salt (0.85 % v/v for 30mins)
5. Vinegar (5 % v/v for 5 mins)

Different storage temperature

Ambient

(Rainy: 36°C ± 2 and Winter: 29°C ± 2)

Cold storage (13°C)

Data collection

- Weight loss (g)
- Decay fruit (%)
- Peel color (scores)
- Fruit firmness (scores)
- Total soluble solids (TSS or Brix %)
- Titratable acidity (TA %)
- Shelf-life (days)

Plate 1 Schematic Diagram for Experimental Set-up

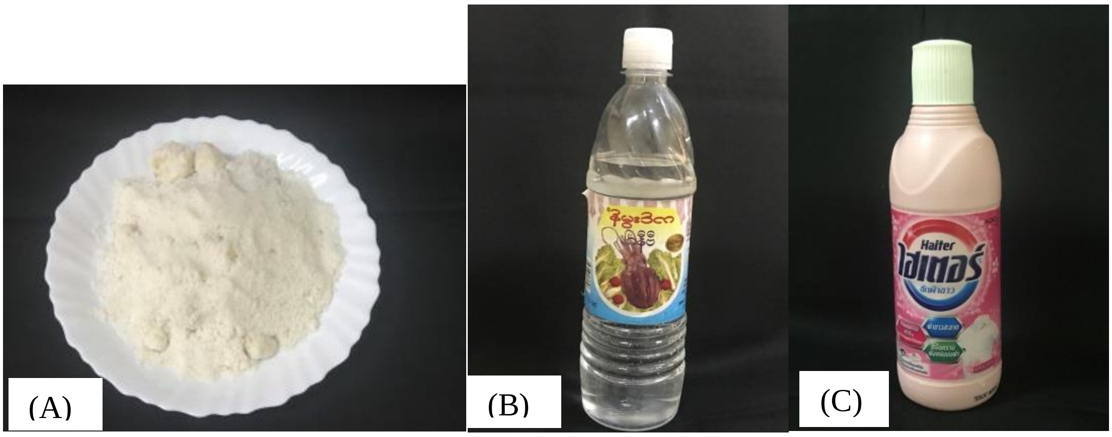


Plate 2 Different sanitizers used in this study (A) Common salt , (B) vinegar and (C) clorox

Dipping sample fruits in sanitizer according to experimental procedure

Air-dry for 15 mins

Plate 3 Preparation for the experiment (A) and (B)

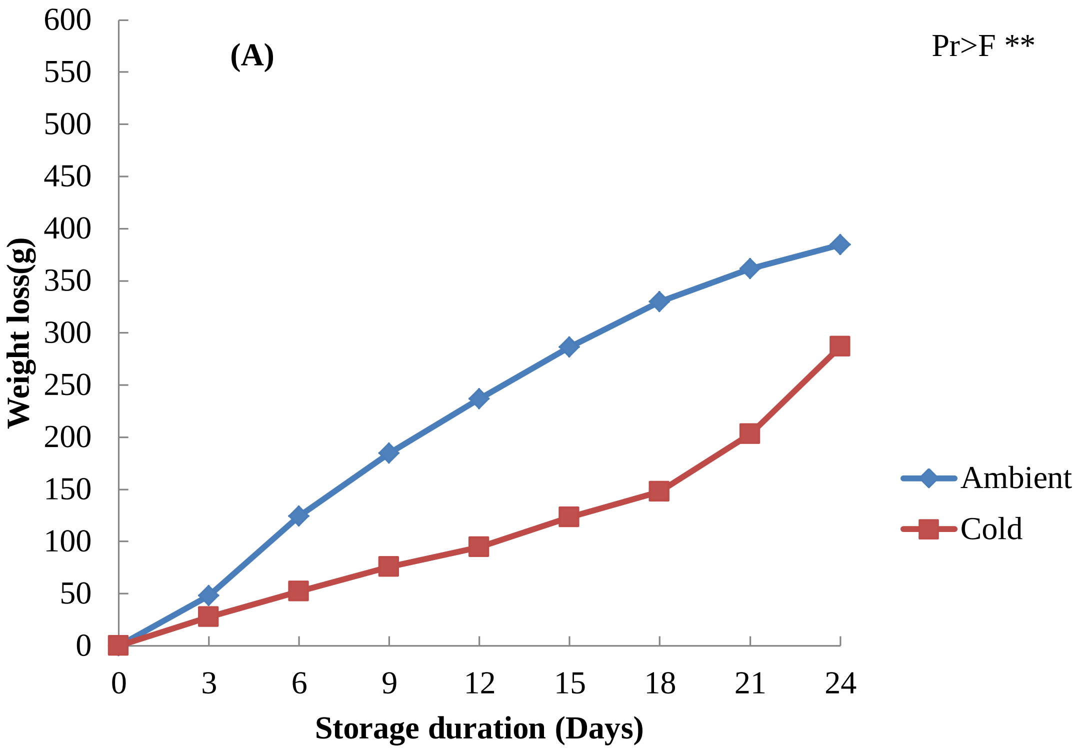
CHAPTER IV

RESULTS AND DISCUSSION

4.1 Weight Loss (g) of Tomato Fruits

Physiological weight loss of weight can influence the economic returns tomato fruit storage. The changes in weight loss (g) of tomato fruit as affected by two storage temperatures and different sanitizers along the storage periods were shown in Figure 4.1 and 4.2. Weight loss were significantly different between two storage conditions in both seasons along the storage periods (Figure 4.1 A and 4.2 A). Weight loss of tomatoes increased progressively during the storage periods, however the rate of weight loss was recorded significantly lower in tomatoes stored inside the cold conditions at all data collection in both seasons. The weight loss of tomato fruits stored under ambient condition was about more than two times higher than that of cold-stored tomatoes at all data collections. This could be due to the effects of low temperature on vapor pressure difference and increased water retention. Gharezi et al. (2012) indicated that the cold storage retained minimum weight loss which is in agreement with the finding of this study.

Weight losses were significantly different among different sanitizer treatments in both seasons along the storage periods (Figure 4.1 B and 4.2 B). At 24 days after storage (DAS), the weight loss was lowest in vinegar-treated fruits(263.9g) followed by water (294.9g), control (339.1g), common salt (349.7g) in rainy season. The highest weight loss was found in clorox- treated fruits (430.7g) but control and common salt-treated fruits were not significantly difference each other (Figure 4.1 B). In winter season, the weight loss was lowest in vinegar-treated fruits (160.3g) followed by control (172.1g), water (205.3g) and clorox (209.1g). The highest weight loss was found in common salt-treated fruits (272.9g) at 24 DAS (Figure 4.2 B). Khaleghi et al. (2013) found that infection of NaCl (common salt) caused accelerated ripening and decaying and also rapid weight loss which is similar to this result.



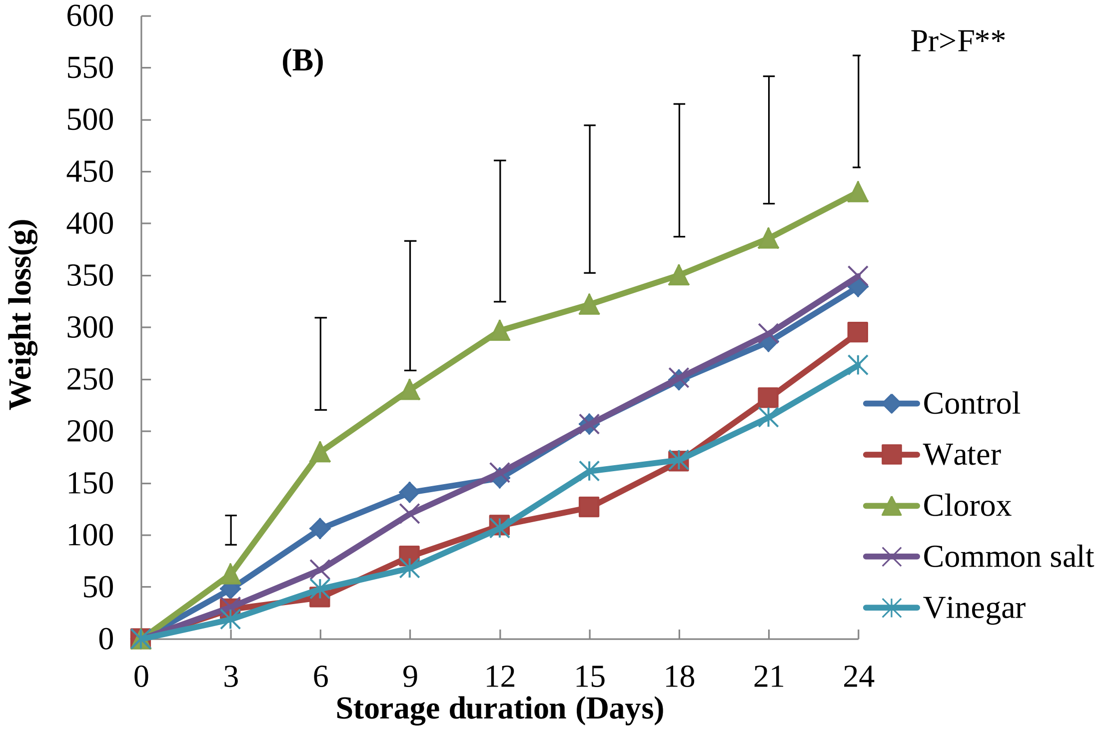


Figure 4.1 Weight loss (g) of tomato fruits as affected by (A) storage temperatures and (B) different sanitizers in rainy season. Vertical bars (I) indicates LSD ($p \leq 0.05$)

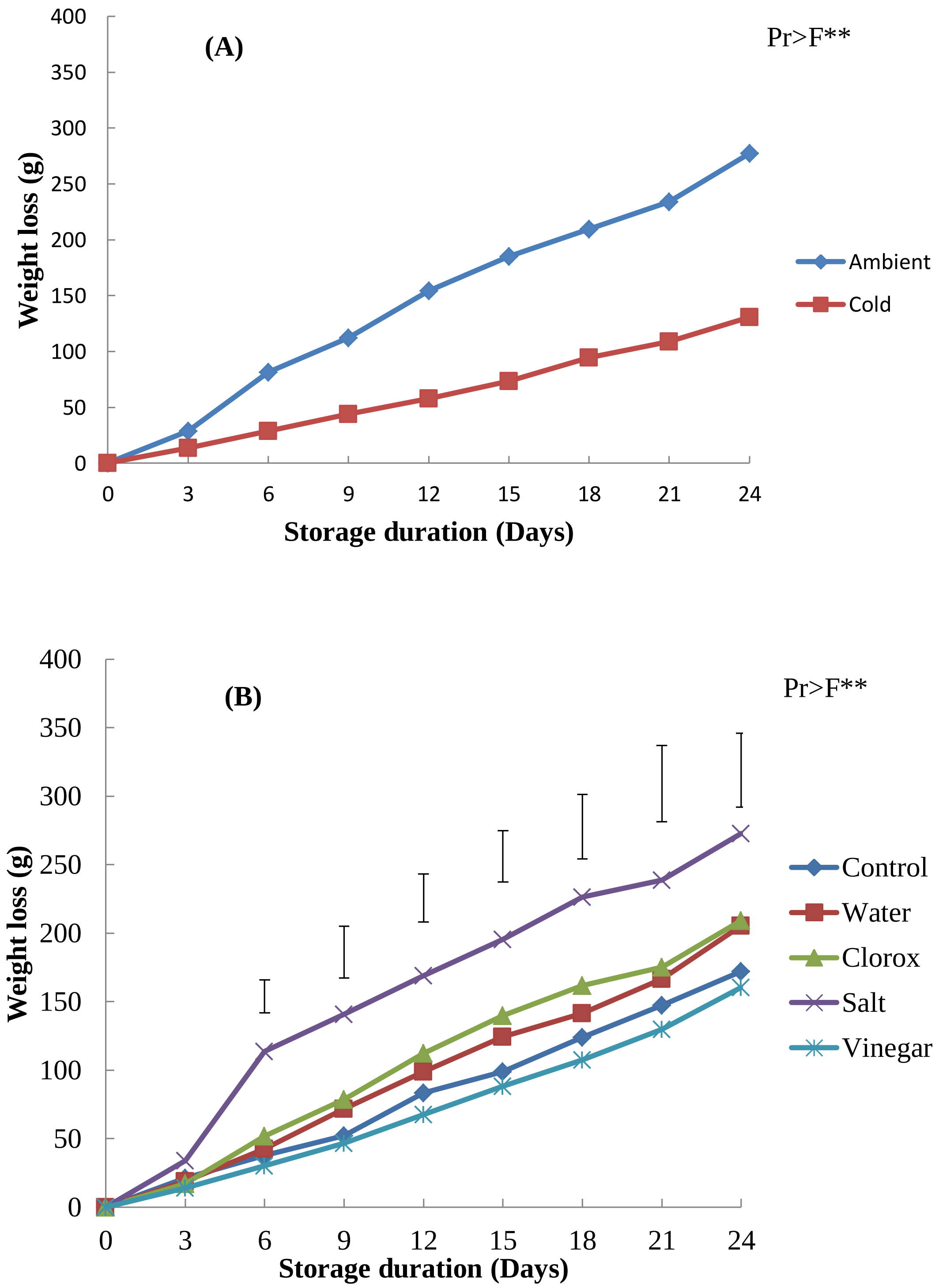
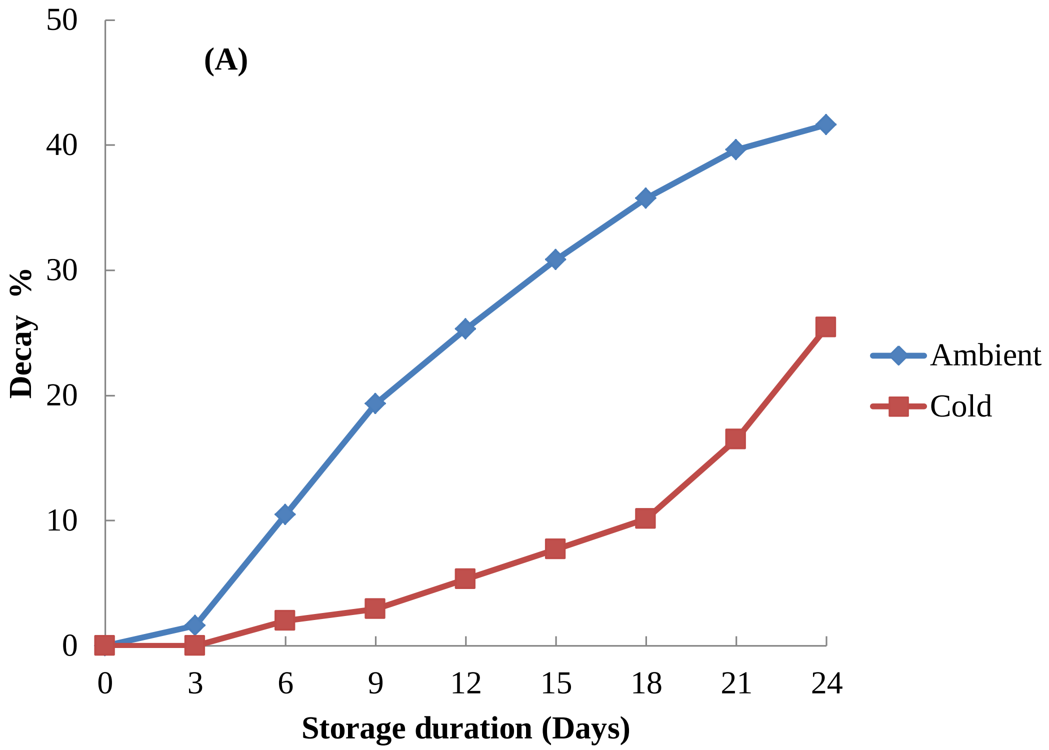


Figure 4.2 Weight loss (g) of tomato fruits as affected by (A) storage temperatures and (B) different sanitizers in winter season. Vertical bars (I) indicates LSD (p ≤ 0.05)

4.2 Decay Fruit (%)

Decay % of tomato fruit as affected by two storage temperatures and different sanitizers along the storage periods were shown in Figure 4.3 and 4.4. Decay fruit % increased with the storage time for all storage conditions in both seasons. Fruits stored in cold conditions showed lower decay fruit % than those stored under ambient condition. In ambient storage condition decay of the fruit starts at 3 DAS while there is no decay fruit under cold storage condition in rainy season (Figure 4.3 A). However, in winter season fruit decay started at 6DAS for two storage conditions decay of fruit starts at 6 DAS (Figure 4.4 A). Fruit deterioration may be due to accelerate fruit ripening and ethylene production. High temperature fastens the rate of fruit ripening, thus fastens the rate of fruit deterioration. This finding is in accordance with the work done by Moneruzzaman et al. (2008) who reported that tomato stored at low temperature decreases the early deterioration percentage. Cold storage temperature slows the rate of fruit ripening and ethylene production (Godana et al. 2015).

In rainy season, the highest decay fruit % was observed in clorox-treated fruits (42.0%) while the lowest was found in vinegar-treated fruits (23.8%) at 24 DAS (Figure 4.3 B). In winter season, decay fruit % was the lowest in vinegar-treated fruits (6.3%) followed by control (7.3%) and water (12%) and then clorox-treated fruits (14.4%) at 24 DAS.. Among sanitizer treatments, common salt-treated (20.1%) fruits were recorded highest decay % which was not different with clorox-treated fruits at 24 DAS. Control and water-soaked fruits were not different in decay fruit % with each other (Figure 4.4 B). In both seasons, the lowest decay fruit % found in the vinegar-treated fruits may be due to the effect of vinegar against most microorganisms (Doores 1993) and decay control (Sholberg et al. 2000).



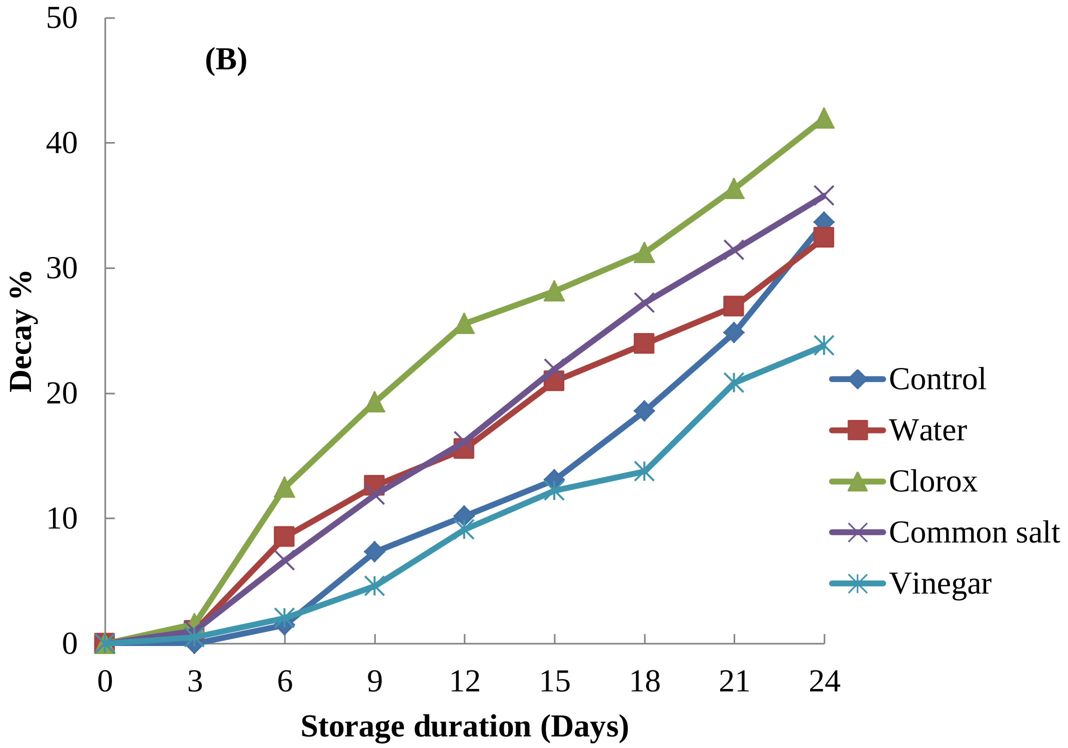


Figure 4.3 Decay fruits % of tomato as affected by (A) storage temperatures and (B) different sanitizers in rainy season. Vertical bars (I) indicates LSD ($p \leq 0.05$)

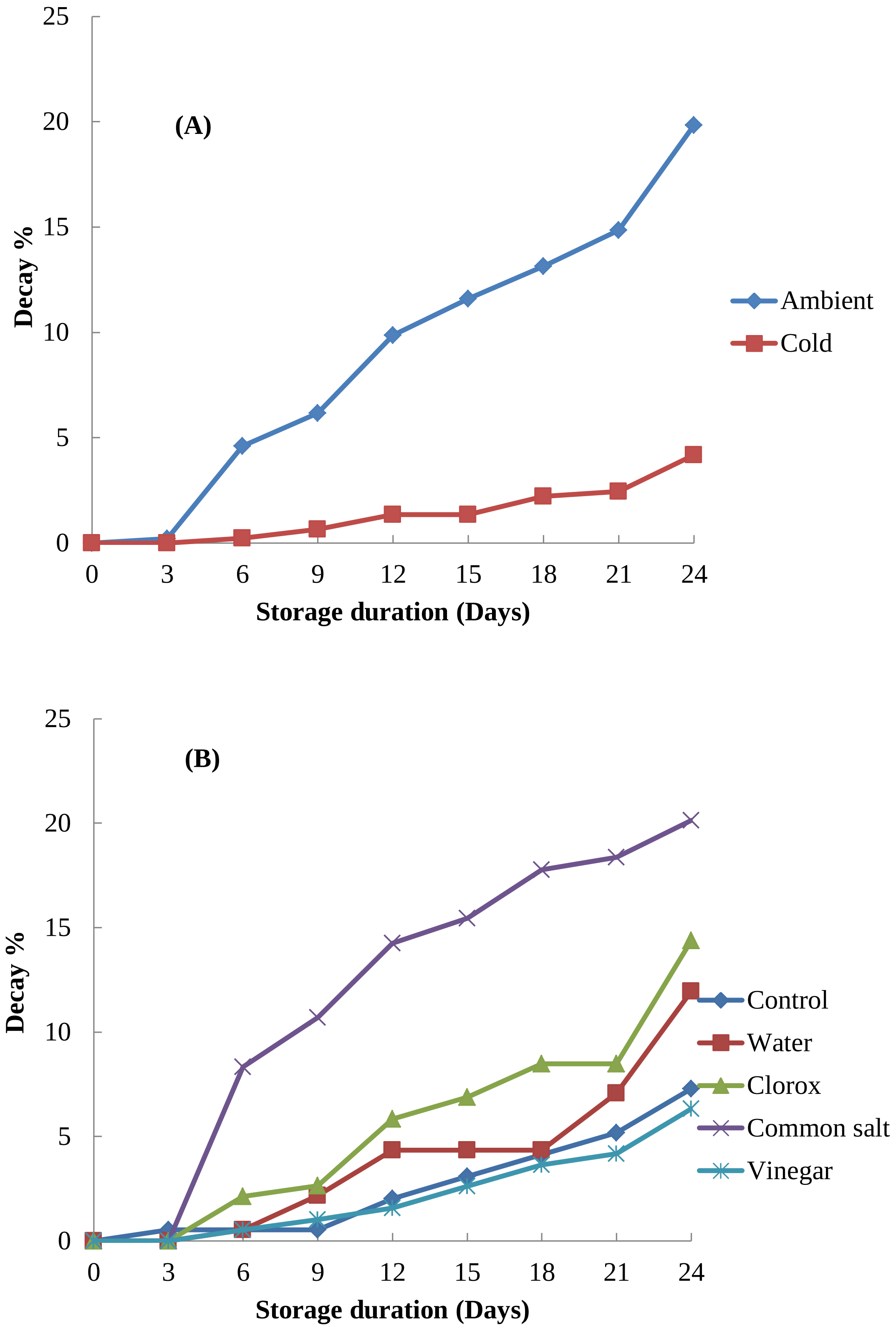


Figure 4.4 Decay fruits % of tomato as affected by (A) storage temperatures and (B) different sanitizers in winter season. Vertical bars (I) indicates LSD ($p \leq 0.05$)

4.3 Changes in Peel Color of Tomato

Peel color changes, one of the indications of physicochemical developmental stages, in tomato fruits were described in Figure 4.5 and 4.6. In rainy season, the fruits showed significant difference in fruit color between two storage conditions at 12 and 15 DAS (Figure 4.5 A). In winter season, there were significant differences between two storage temperatures along the storage period until the fruits reached the full ripening (Figure 4.6 A). In both seasons, the cold storage condition could delay their color development of tomato fruits than those stored under ambient condition. Perhaps, the slower changes in color at low temperature decrease not only the production of ethylene but also the rate of response of the tissues to ethylene. And then it can delay the fruits ripening. During the storage period, there was a gradual increase in tomato fruit skin color from pink stage to red ripe stage at the end of the storage period. Campbell et al. (1990) stated that during normal ripening of tomato fruit, tissue color changes from green through pink to red, coincide with ethylene biosynthesis and a climacteric rise in respiration.

The color of tomato fruits were significantly different among sanitizer treatments at 3 to 15 DAS in rainy season (Figure 4.5 B). But there were significant differences among sanitizer treatments at 3, 6 and 9 DAS in winter season (Figure 4.6 B). In both seasons, all tomato fruits become fully red at 15 DAS in all treatments. The vinegar-treated fruits gave the slower changes in color and control fruits showed fully red color earlier than the other treatments. The fruits treated with water, clorox and common salt were not significantly different with each other in color changes at 9 DAS. There is no interaction effect between temperature and sanitizer treatments.

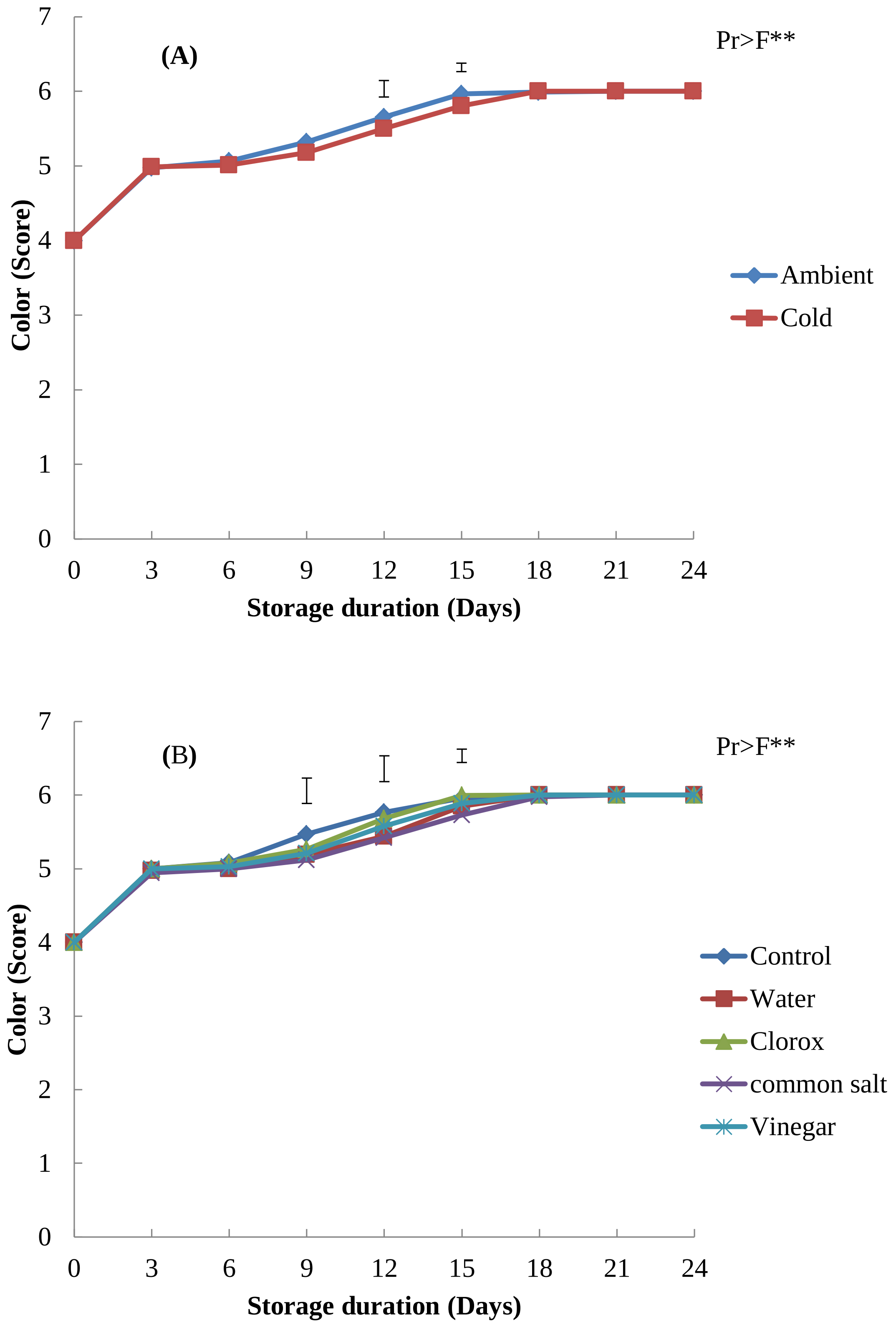
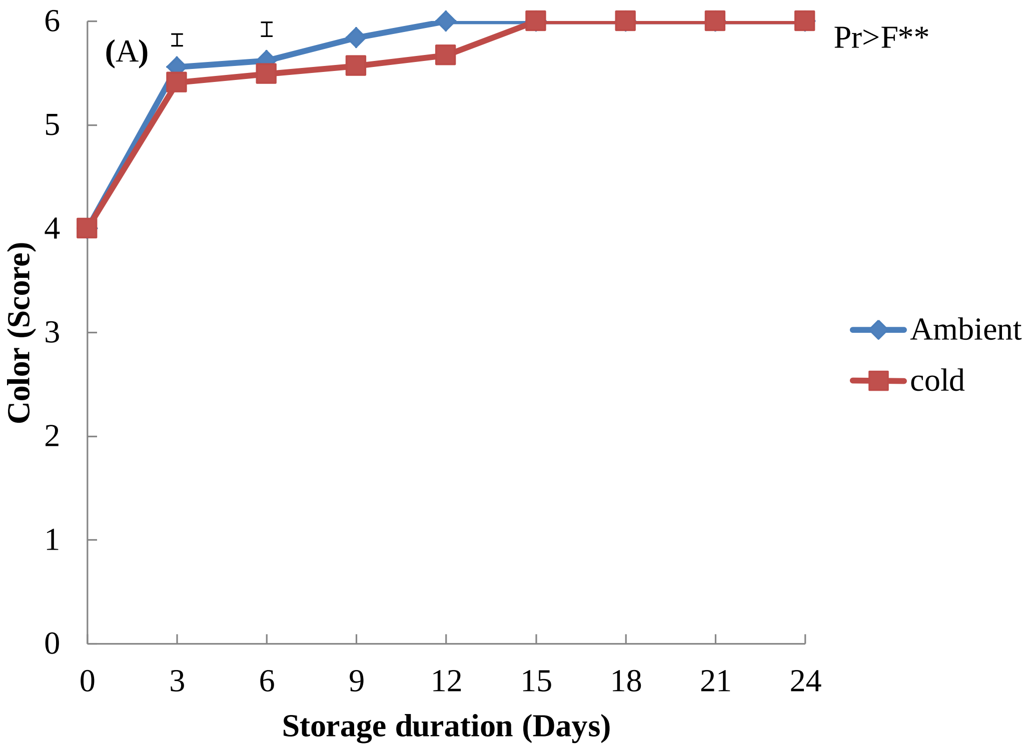


Figure 4.5 Changes in peel color of tomato as affected by (A) storage temperatures and (B) different sanitizers in rainy season. Vertical bars (I) indicates LSD ($p \leq 0.05$)



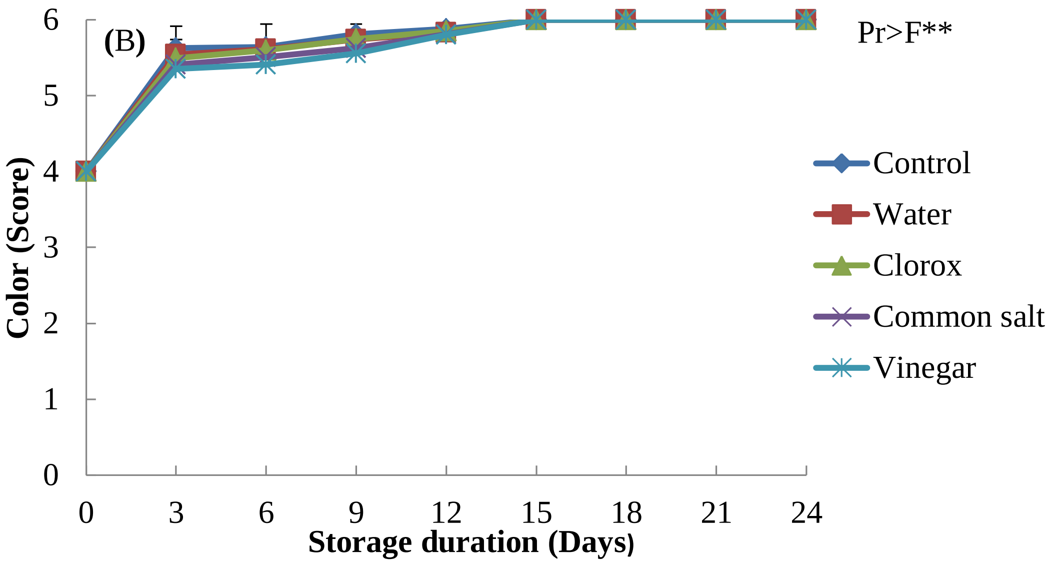


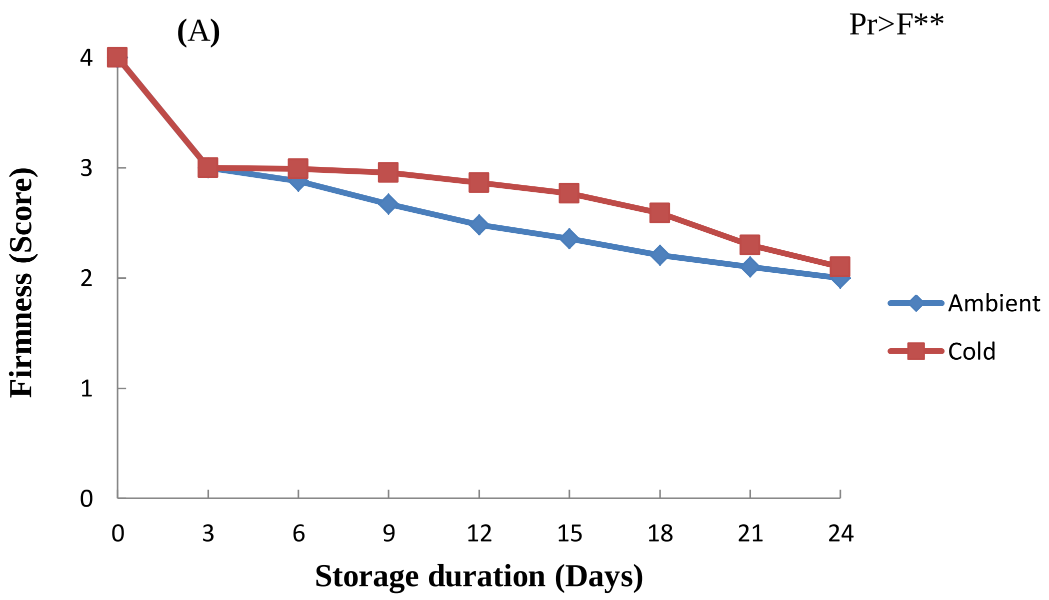
Figure 4.6 Changes in peel color of tomato as affected by (A) storage temperatures and (B) different sanitizers in winter season. Vertical bars (I) indicates LSD ($p \leq 0.05$)

4.4 Changes in Fruit Firmness

The changes in firmness of tomato fruit as affected by two storage temperatures and different sanitizers along the storage periods were shown in Figure 4.7 and 4.8. The firmness of tomato fruit was gradually decreased in all treatment during the storage period. In both seasons, there was a significant effect of different storage conditions in firmness of tomato fruits as described in Figure 4.7 A and 4.8 A. the fruits stored under ambient condition became significantly softer than those in cold room in both seasons. All fruits softened progressively during storage showing that firmness of tomato was influenced by temperature and storage time. Lana et al. (2005) indicated that the firmness of tomatoes decreased during storage, which is in agreement with the present findings. The reason of lower firmness could be attributed to higher rate of metabolic activities and activity of cell wall degrading enzymes that loosens the fruit skin which result in higher permeability of the cell for higher rate of moisture loss in ambient storage tomatoes than in cold room. Moisture loss also induces wilting, shrinkage, and loss of firmness (Mohammed et al. 1999). Cold-stored tomatoes had higher firmness than those stored under ambient condition along the storage periods in winter season. That could be due to lower water loss at low temperature from fruit (Beaulieu and Gorny 2001).

In rainy season, there was highly significant difference in firmness among the different sanitizer treatments along the storage period (Figure 4.7 B). The clorox-treated fruits gave the lowest firmness among sanitizer treatments. The fruits treated with vinegar, common salt, control and water were not significantly different with each other. In winter season, the changes in firmness of tomato fruits were highly and significantly different among different sanitizers at (6, 9, 15, and 18 DAS) (Figure 4.8 B). The vinegar-treated fruits showed higher firmness than the other treatments while the lower firmness was found in, clorox, common salt and control fruits. Common salt (NaCl) has dehydrated action resulting from decreased turgor as a cause of tissue softening (Khaleghi et al. 2013). David et al. (1998) demonstrated that clorox efficiently promote the enzymatic hydrolysis of cell wall cellulose perhaps decrease in tomato firmness.

There is no interaction effect between temperature and sanitizer treatments.



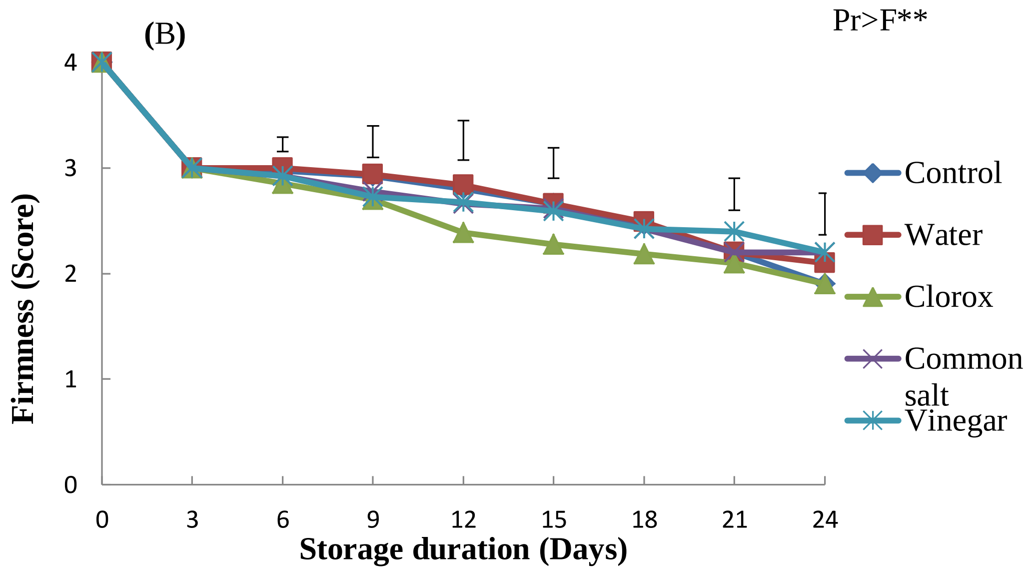


Figure 4.7 Changes in fruit firmness as affected by (A) storage temperatures and (B) different sanitizers in rainy season Vertical bars (I) indicates LSD ($p \leq 0.05$

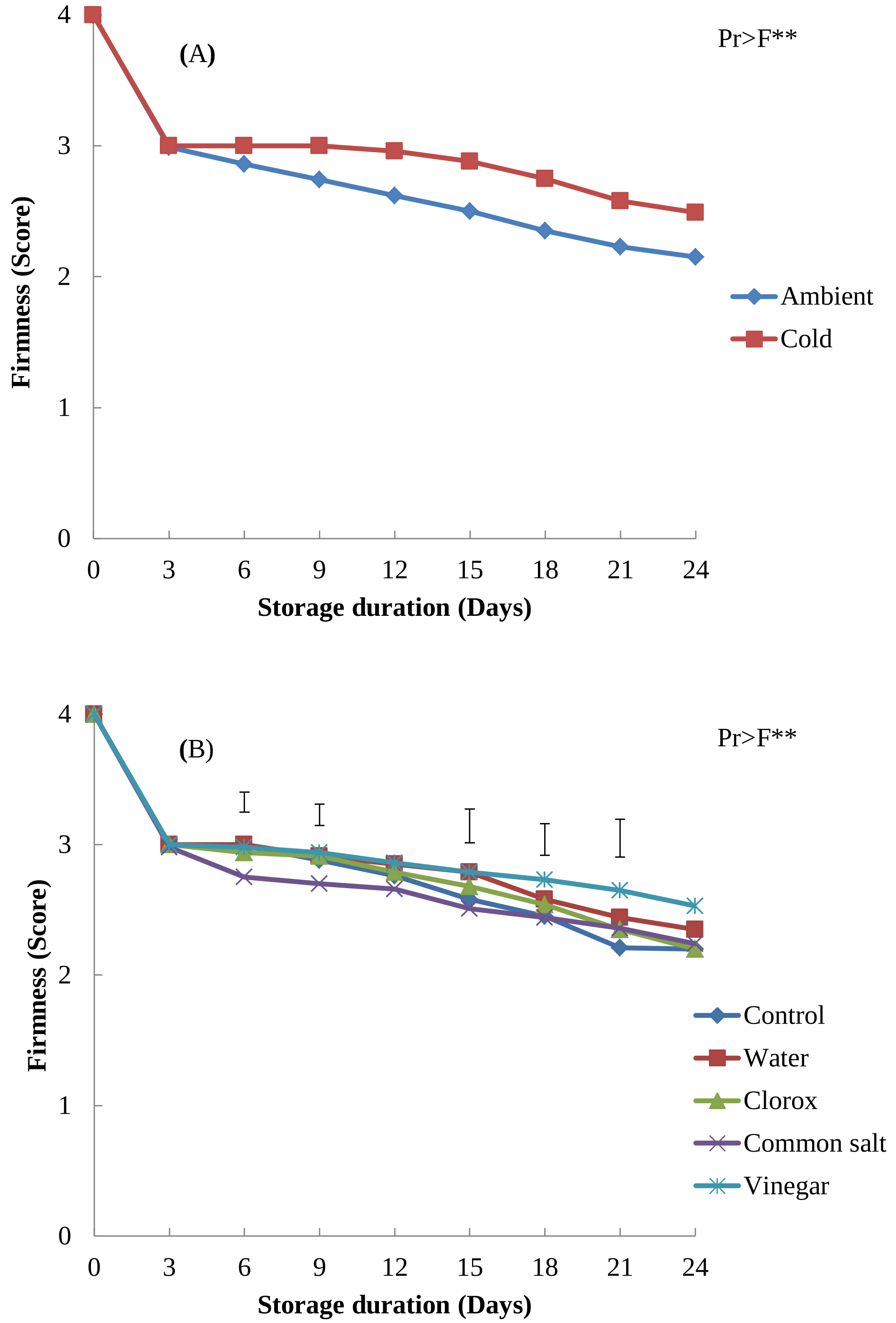


Figure 4.8 Changes in fruit firmness as affected by (A) storage temperatures and (B) different sanitizers in winter season. Vertical bars (I) indicates LSD ($p \leq 0.05$)

4.5 pH of Tomato Fruit Juice

The changes in pH of tomato fruit juice as affected by two storage temperatures and different sanitizers along the storage periods were shown in Table 4.1 and 4.2. The pH contents were significantly different among storage temperature at all observations in both seasons (Table 4.1and 4.2) except at 3 DAS in winter season. The lower pH content recorded in cold storage may be due to a reduction in the metabolic processes when stored under low temperatures (Batu 2004). Tigist et al. (2013) mentioned that lower pH values were positively correlated with the slower rate of respiration and better quality maintenance which is consistent with this finding.

The pH content of the tomato was significantly affected by different sanitizers at all observations in rainy season (Table 4.1) and only at 3 DAS in winter season (Table 4.2). Among different sanitizers, mean pH was lowest (4.16) in vinegar-treated fruits and the highest pH (4.23) was observed in clorox-treated fruits at 18 DAS in rainy season. In winter season, the lowest pH content of tomato was observed in vinegar-treated fruits (3.99) than the other different sanitizer treatments while fruits treated with water, clorox, common salt and control were not significantly different with each other at 9 DAS. The pH content of the tomato gradually increased along storage duration ranging from 3.99 to 4.23 in both seasons. Babitha and Kiramanyi (2010) observed pH range of 4.0 - 4.5 in different varieties of tomatoes which is nearly similar to the findings of present study.

Table 4.1 pH of tomato fruit juice as affected by two storage temperatures and different sanitizers in rainy season

Treatment	pH					
	3DAS	**6DAS**	**9DAS**	**12DAS**	**15DAS**	**18DAS**
Ambient	4.08 a	4.12 a	4.15 a	4.17 a	4.21 a	4.23 a
Cold	4.04 b	4.06 b	4.11 b	4.11 b	4.14 b	4.17 b
Pr≥F	**	**	*	*	**	**
LSD	0.0205	0.0200	0.0464	0.0331	0.0264	0.0241
Control	4.08 a	4.10 ab	4.13 abc	4.16 a	4.18 a	4.21 ab
Water	4.08 a	4.13 a	4.15 ab	4.17 a	4.18 a	4.21 ab
Clorox	4.05 a	4.08 b	4.12 bc	4.14 a	4.21 a	4.23 a
Salt	4.08 a	4.11 ab	4.19 a	4.15 a	4.17 ab	4.20 bc
Vinegar	4.01 b	4.04 c	4.06 c	4.09 b	4.13 b	4.16 c
Pr≥F	**	**	*	**	*	**
LSD	0.0324	0.0316	0.0734	0.0523	0.0417	0.0382
CV%	0.78	0.75	1.73	1.23	0.97	0.89

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Table 4.2 pH of tomato fruit juice as affected by two storage temperatures and different sanitizers in winter season

Treatment	pH					
	3DAS	**6DAS**	**9DAS**	**12DAS**	**15DAS**	**18DAS**
Ambient	4.05	4.07 a	4.12 a	4.15 a	4.19 a	4.24 a
Cold	4.22	3.97 b	3.99 b	4.02 b	4.04 b	4.07 b
Pr≥F	ns	**	**	**	**	**
LSD	0.6163	0.0347	0.0325	0.0407	0.0376	0.0395
Control	4.00	4.04	4.08 a	4.11	4.12	4.142
Water	4.76	4.05	4.08 a	4.08	4.13	4.17
Clorox	3.98	4.04	4.08 a	4.11	4.13	4.17
Salt	4.01	4.01	4.05 a	4.09	4.14	4.18
Vinegar	3.94	3.98	3.99 b	4.04	4.08	4.12
Pr≥F	ns	ns	*	ns	ns	ns
LSD	0.9745	0.0549	0.0515	0.0644	0.0595	0.0624
CV%	22.96	1.33	1.24	1.54	1.41	1.46

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

4.6 Titratable Acidity (TA %)

The changes in titratable acidity (TA %) of tomato fruit juice as affected by two storage temperatures and different sanitizers along the storage periods were shown in Table 4.3 and 4.4. The TA% of tomato gradually decreased along the storage duration at all postharvest treatments. The TA % of tomato were significantly different between two storage temperatures along the storage periods in both seasons (Table 4.3 A and 4.4 A). Tomato in cold storage was higher TA % than ambient storage condition in both seasons. Higher loss of titratable acidity during the storage time under ambient condition could be related to higher respiration rate at higher temperature as ripening advances where organic acids are used as substrate in the respiration process (Lurie and Klein 1990).

The content of TA% in tomato showed significant differences among different sanitizers along the storage periods in both seasons (Table 4.3 B and 4.4 B). Vinegar-treated fruits were recorded significantly highest titratable acidity among all sanitizer treatments at all data collections in rainy season. Similarly, in winter season, the highest TA% was observed in vinegar-treated fruits throughout the storage periods. In both seasons, no interaction effect was observed between temperature and sanitizer treatments.

Fruits treated with vinegar had higher acidity throughout the period of study. Bhatnagar and Gautam (2006) stated that the fruit itself might utilize the acid during storage so that the acid in the fruits decreases which is contradicted with this finding presented. But the result of this study were consistent with the findings of Gharezi et al. (2012) who reported that vinegar-treated cherry tomato had lower pH and higher titratable acidity.

Lambeth et al. (1966) observed the contents of citric acid ranging from 0.4% to 0.91%, which is in agreement with the present study. Tilahum (2013) noted that the increase in pH was paralleled by a decreased in TA % which is consented with the result of present study. It is a measure of all aggregate acids and some of all volatile and fixed acids. The changes in organic acids during ripening have been attributed to a rise in citrate and fall in malate, indicating a change in metabolism of citrate and reduction in the level of citric acid (Sanchez-Mereno et al. 2006).

Table 4.3 Titratable acidity (TA%) of tomatoes as affected by two storage temperatures and different sanitizers in rainy season

Treatment	Titratable acidity (TA%)					
	3DAS	**6DAS**	**9DAS**	**12DAS**	**15DAS**	**18DAS**
Ambient	0.76 b	0.68 b	0.63 b	0.57 b	0.51 b	0.45 b
Cold	0.80 a	0.73 a	0.68 a	0.62 a	0.57 a	0.52 a
Pr≥F	**	**	*	**	**	**
LSD	0.0271	0.0321	0.0382	0.0327	0.0225	0.0268
Control	0.75 c	0.69 b	0.64 b	0.59 b	0.54 b	0.48 b
Water	0.74 c	0.68 b	0.64 b	0.56 b	0.51 b	0.44 c
Clorox	0.75 c	0.68 b	0.64 b	0.57 b	0.52 b	0.46 bc
Salt	0.81 b	0.70 b	0.66 b	0.59 b	0.51 b	0.48 b
Vinegar	0.86 a	0.77 a	0.73 a	0.67 a	0.62 a	0.56 a
Pr≥F	**	*	*	**	**	**
LSD	0.0429	0.0508	0.0603	0.0517	0.0355	0.0423
CV%	5.36	7.05	8.92	8.47	6.43	8.54

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Table 4.4 Titratable acidity (TA%) of tomatoes as affected by two storage temperatures and different sanitizers in winter season

Treatment	Titratable acidity (TA%)					
	3DAS	**6DAS**	**9DAS**	**12DAS**	**15DAS**	**18DAS**
Ambient	0.60 b	0.55 b	0.52 b	0.46 b	0.42 b	0.36 b
Cold	0.68 a	0.63 a	0.55 a	0.49 a	0.45 a	0.41 a
Pr≥F	**	**	**	*	*	*
LSD	0.0172	0.0169	0.0235	0.0265	0.0296	0.0279
Control	0.55 d	0.52 c	0.48 d	0.45 b	0.42 b	0.38 b
Water	0.62 c	0.58 b	0.53 b	0.47 b	0.43 b	0.40 b
Clorox	0.63 c	0.59 b	0.53 bc	0.45 b	0.40 b	0.37 b
Salt	0.67 b	0.58 b	0.49 cd	0.46 b	0.42 b	0.36 b
Vinegar	0.73 a	0.67 a	0.62 a	0.54 a	0.50 a	0.46 a
Pr≥F	**	**	**	**	**	**
LSD	0.0272	0.0267	0.0371	0.0420	0.0468	0.0441
CV%	4.14	4.40	6.79	8.66	10.53	10.92

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

4.7 Total Soluble Solids Contents (Brix %)

The changes in total soluble solid (TSS) of tomato fruit juice as affected by two storage temperatures and different sanitizers along the storage periods were shown in Table 4.5 and 4.6. In rainy season, the maximum value in TSS was observed at 9 DAS in all treatments. The highly and significantly differences in TSS were observed between two storage conditions at 15 and 18 DAS in rainy season (Table 4.5) and at 8,15 and 18 DAS in winter season (Table 4.6). Tomato in cold storage had higher TSS content than ambient storage condition in both seasons. Increase in TSS of tomato fruits could be due to excessive moisture loss which increases concentration as well as the hydrolysis of carbon hydrates to soluble sugars (Waskar et al. 1999 and Nath et al. 2011). However, in this study, higher TSS under cold storage condition may be due to slower respiration rate at low temperature resulting in higher soluable sugars in the fruits as respiratory substrates (Kays and Paull 2004).

In rainy season, there were significant differences in TSS among the different sanitizers only at 3, 15 and 18 DAS. Among sanitizer treatments at 18 DAS, mean TSS content of tomato was lowest in vinegar-treated fruits (4.65%) which was not significantly different with control fruits (4.91%). The highest value was recorded in common salt-treated fruits (5.38%) and clorox-treated fruits (5.31%) (Table 4.5). In the winter season, there were significant differences among the different sanitizers at 12, 15 and 18 DAS. The significant lowest TSS content was found in vinegar- treated fruits (4.69%) than the other treatments (Table 4.6) while fruits treated with water, clorox, common salt and control were not significantly different with each other. The reason of lower TSS in vinegar-treated fruits may be related to the nature of the natural product and/or the putative interaction between plant tissue and vapors (Tzortzakis et al. 2011)

In general, the values commonly obtained for soluble solids of different varieties of tomato fruit range from 4 to 6 Brix % (Cramer et al. 2001) which is in agreement with this finding presented.

Table 4.5 Total soluble solids (brix %) of tomatoes as affected by two storage temperatures and different sanitizers in rainy season

Treatment	Total soluble solids (%)					
	3DAS	**6DAS**	**9DAS**	**12DAS**	**15DAS**	**18DAS**
Ambient	4.71	5.52	5.62	4.84	4.88 b	4.91 b
Cold	4.80	5.40	5.77	4.80	5.36 a	5.25 a
Pr≥F	ns	ns	ns	ns	**	**
LSD	0.2104	0.2339	0.2702	0.2906	0.3060	0.2021
Control	4.92 a	5.26	5.738	4.64	5.18 a	4.91 bc
Water	4.82 a	5.56	5.58	4.86	5.26 a	5.15 ab
Clorox	4.77 a	5.68	6.00	5.07	5.34 a	5.31 a
Salt	4.87 a	5.57	5.68	4.77	5.24 a	5.38 a
Vinegar	4.41 b	5.24	5.49	4.76	4.58 b	4.65 c
Pr≥F	*	ns	ns	ns	*	**
LSD	0.3326	0.3699	0.4272	0.4595	0.4839	0.3196
CV%	6.82	6.60	7.31	9.29	9.22	6.13

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Table 4.6 Total soluble solids (brix%) of tomatoes as affected by two storage temperatures and different sanitizers in winter season

Treatment	Total soluble solids (brix %)					
	3DAS	**6DAS**	**9DAS**	**12DAS**	**15DAS**	**18DAS**
Ambient	4.85	5.19	4.99 b	4.97	5.14 b	4.97 b
Cold	4.85	5.20	5.23 a	4.77	5.48 a	5.32 a
Pr≥F	ns	ns	*	ns	*	**
LSD	0.2518	0.1696	0.2314	0.2077	0.2797	0.2231
Control	5.03	5.29	5.09 ab	5.16 a	5.46 a	5.27 a
Water	4.99	5.18	5.29 a	4.86 a	5.63 a	5.38 a
Clorox	4.98	5.41	5.16 a	4.97 a	5.27 a	5.31 a
Salt	4.70	5.14	5.28 a	4.89 a	5.39 a	5.08 a
Vinegar	4.54	5.03	4.76 b	4.49 b	4.79 b	4.69 b
Pr≥F	ns	ns	*	**	**	**
LSD	0.3982	0.2681	0.3659	0.3284	0.4422	0.3527
CV%	8.01	5.03	6.97	6.57	8.12	6.68

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

4.8 Remaining weight of tomatoes

Table 4.7 and 4.8 showed changes in remaining weight of tomato fruits in terms of gram (g) and percentage (%) at 18 and 24 DAS in rainy season and at 24 and 30 DAS in winter season. In both seasons, remaining weight was significantly different between two storage conditions and among different sanitizers at those times. In general, remaining weight of tomatoes gradually decreased during the storage period, and significantly lower remaining weight was recorded in tomatoes stored under ambient condition at 18 and 24 DAS in rainy season. Moreover, ambient condition also gives significantly lower remaining weight at 24 and 30 DAS in winter season. Tomato in cold room exhibited 24.2% higher remaining weight than ambient condition at 30 DAS. It may be due to lower relative humidity under ambient condition than that in cold room (Appendix table 11 and 12). Tomato has high moisture content and therefore is very difficult to store at ambient temperatures for a long time. This finding is in accordance with the work done by Moneruzzaman et al. (2009) who reported that storage of tomato at low temperature and high relative humidity decrease the early fruit deterioration and water loss.

Among different sanitizers, water- and vinegar-treated fruits and control could retain higher weight than the other sanitizers in rainy season at 18 and 24 DAS (Table 4.7). That could be due to the fact that soaking in water and vinegar can cause reduction in food-borne diseases. In winter season, vinegar- and water-treated fruits showed about 10 % higher remaining weight than other sanitizers at 18 DAS. However, at 24 DAS, vinegar-treated fruits could retain the highest remaining weight among all sanitizers used and the value was about 6% higher than water-soaked one (Table 4.8). Vinegar reduced microbial loads on the fruits. Peter et al. (2011) pointed out that decay in tomato fruits can also be controlled by vinegar vapor treatment.

Table 4.7 Remaining weight of tomatoes as affected by two storage temperatures and different sanitizers at 18 DAS and 24 DAS in rainy season

Treatment	Remaining weight			
	18 DAS		24 DAS	
	gram (g)	percent (%)	gram (g)	percent (%)
Ambient	424.76 b	56.6	366.70 b	48.9
Cold	604.79 a	80.6	463.34 a	61.8
Pr≥F	**		**	
LSD	55.335		46.452	
Control	513.15 ab	68.4	413. 71 ab	55.2
Water	571.74 ab	76.1	420.52 ab	56.0
Clorox	400.89 c	53.5	324.26 c	43.2
Salt	498.72 b	66.5	400.34 b	53.4
Vinegar	589.38 a	78.6	486.27 a	56.1
Pr≥F	**		**	
LSD	87.492		73.447	
CV%	16.57		17.25	

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Table 4.8 Remaining weight of tomatoes as affected by two storage temperatures and different sanitizers at 24 DAS and 30 DAS in winter season

Treatment	Remaining weight (g)			
	24 DAS		30 DAS	
	gram (g)	percent (%)	gram (g)	percent (%)
Ambient	425.60 b	56.7	322.27 b	42.9
Cold	577.63 a	77.0	503.65 a	67.2
Pr≥F	**		**	
LSD	24.404		28.659	
Control	503.88 b	67.2	430.13 ab	57.4
Water	549.75 a	73.3	425.56 b	56.7
Clorox	499.56 b	66.6	413.31 b	55.1
Salt	403.81 c	53.8	322.31 c	42.9
Vinegar	551.06 a	73.5	473.50 a	63.1
Pr≥F	**		**	
LSD	38.586		45.314	
CV%	7.50		10.70	

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

4.9 Shelf-life (Days)

The shelf-life of tomato fruits as affected by two storage temperatures and different sanitizers along the storage periods were presented in Figure 4.9 and 4.10. The shelf life was significantly different between two storage temperatures in both seasons. In rainy season, the significantly longer shelf life of tomato (24 days) was noted in cold storage than ambient condition (Figure 4.9 A). Moreover, the longer shelf life of cold-stored tomatoes (30 days) was observed in winter season (Figure 4.10 A). The longer shelf-life at low temperature may be due to delayed fruit ripening and reduction in decay fruit (Godana et al. 2015).

The shelf-life of tomatoes was significantly different among different sanitizer treatments in both seasons (Figure 4.9 B and 4.10 B). In the rainy season, the longest shelf-life were found in water (24 days) and vinegar-treated (24 days) fruits (Figure 4.9 B). But control and common salt were not significantly different with each other. As a result, water and vinegar are suitable sanitizers for rainy season but water is more appropriate than the vinegar by the reason of saving money. In winter season, the longest shelf life of tomato was found in vinegar-soaked fruits (30 days) (Figure 4.10 B). On the other hand, the fruits soaked in water and clorox were not significantly different with each other while control and common salt did not differ significantly from each other. Vinegar can also have reduced microbial infections for fruits. Peter et al. (2011) found that tomato fruit decay can be controlled by vinegar vapor treatment and storade at 20˚C.

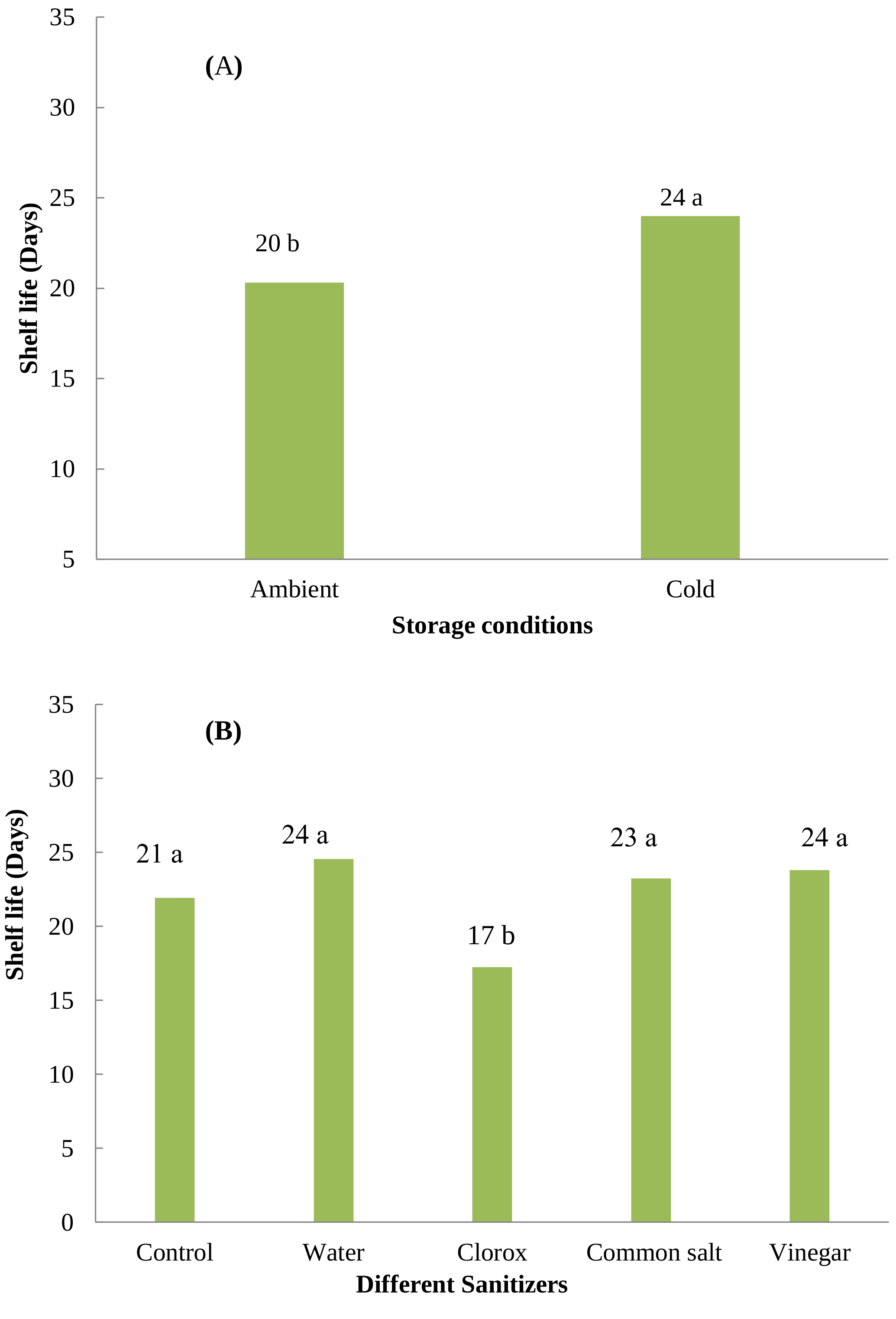


Figure 4.9 Shelf life of tomato as affected by (A) storage temperatures and (B) different sanitizers in rainy season.

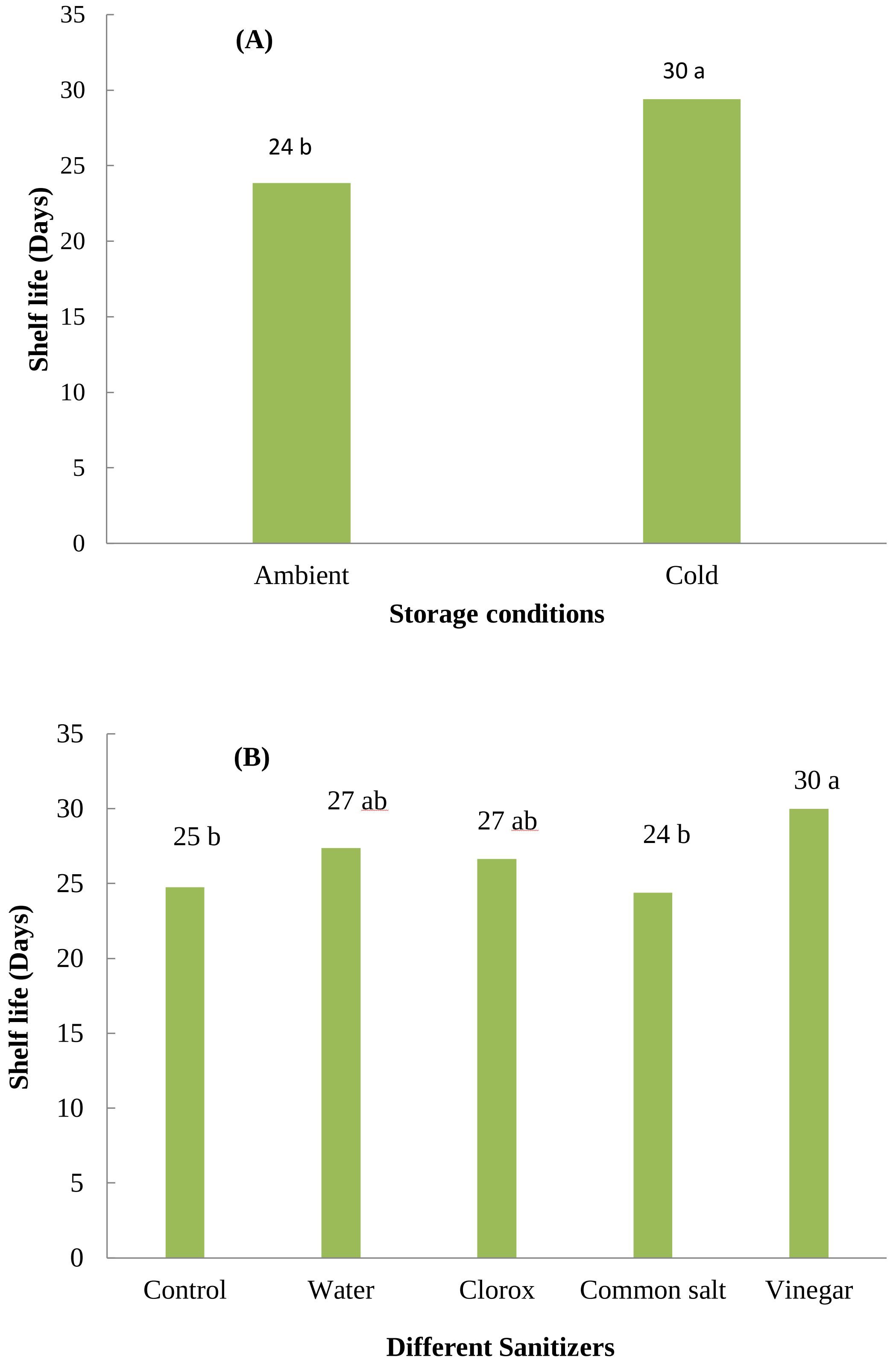


Figure 4.10 Shelf life of tomato as affected by (A) storage temperatures and (B) different sanitizers in winter season

CHAPTER V
CONCLUSION

In this study, the postharvest quality of fresh tomatoes was assessed by using different sanitizers and storing the fruits under two storage temperatures in rainy and winter season. Tomatoes in cold storage were found to have better appearance and longer shelf-life, 24 days in rainy season and 30 days in winter season, than those under ambient conditions, 20 days in rainy season and 24 days in winter season. Moreover, reduction in weight loss and decay fruit percent were observed in cold-stored tomatoes.

Among tested sanitizers, water can be considered as the best sanitizer with the longer shelf-life (24 days) than the other sanitizers in rainy season. Although vinegar-treated fruits also have longer shelf-life (24 days), the cost is more expensive than the water. So, water should be used to clean tomato fruits in rainy seasons. On the other hand, the shortest shelf-life (17 days) and higher weight loss (350.4g) were observed in clorox-treated fruits in rainy season. In winter season, the longest shelf-life (30 days) was found in vinegar-treated fruits among different sanitizers. Vinegar treated fruits could maintain fruit firmness, acidity, and reduce decay fruits % and weight loss. Moreover, it could retain the highest remaining weight among all sanitizers used and the value was about 6% higher than water-soaked one at the end of the storage periods.

According to the results, it was concluded that the tomato fruits harvested at pink stage should be stored in cold room (13°C) to get maximum shelf-life in both seasons and vinegar should be used as sanitizer to reduce weight loss and to maintain good quality of tomato cv. “Kyauk Mae Gaung Sein” fruit in winter seasons. Further experiments are suggested to improve postharvest quality of different tomato varieties and various vinegar concentrations in order to maintain fruit quality for a long time.

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APPENDICIES

Appendix 1. Weight loss (g) of tomato as affected by storage temperatures and different sanitizers in rainy season.

Treatment	Weight loss									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30DAS
Ambient	48.0 a	124.2 a	184.6 a	236.9 a	286.1 a	329.7 a	361.7 a	384.30 a	400.12 a	414.49
Cold	27.5 b	52.1 b	75.4b	94.5 b	123.4 b	147.9 b	202.9 b	287.03 b	301.10 b	402.74
Pr≥F	**	**	**	**	**	**	**	**	*	
LSD	11.980	37.468	52.642	57.277	59.753	53.817	51.856	45.380	46.433	
Control	48.1 ab	106.0 b	141.2 b	154.9 b	206.5 b	249.3 b	286.2 b	339.1 b	470.24 ab	571.00
Water	28.8 c	40.0 c	79.7 b	109.5 b	126.6 b	170.7 b	231.9 b	294.9 bc	425.86 b	501.00
Clorox	62.5 a	180.0 a	240.0 a	297.1 a	322.1 a	350.4 a	385.9 a	430.7 a	465.43 ab	-
Common salt	30.5 bc	66.9 bc	120.7 b	160.2 b	206.8 b	251.3 b	293.9 b	349.7 b	484.16 a	560.16
Vinegar	18.9 c	48.0 bc	68.4 b	106.6 b	161.7 b	172.6 b	213.5 b	263.9 c	427.29 b	507.19
Pr≥F	**	**	**	**	**	**	**	**	*	
LSD	18.9	59.243	83.234	90.563	94.477	85.092	81.991	71.752	46.433	
CV	48.87	65.49	62.42	53.28	44.98	34.73	28.31	20.84	21.22	

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 2. Weight loss (g) of tomato as affected by storage temperatures and different sanitizers in winter season.

Treatment	Weight loss (g)									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30DAS
Ambient	28.7 a	81.3 a	112.1 a	154.4 a	185.3 a	209.7 a	233.8 a	277.3 a	382.80 A	427.73 A
Cold	13.6 b	29.0 b	43.9 b	58.1 b	73.6 b	94.7 b	109.1 b	130.6 b	205.45 B	246.35 B
Pr≥F	*	**	**	**	**	**	**	**	**	**
LSD	12.488	10.120	15.866	14.786	15.801	19.790	23.430	22.845	31.436	28.470
Control	21.1	37.6 b	52.1 c	83.3 cd	99.1 c	124.0 cd	147.3 bc	172.1 cd	261.44 b	319.88 bc
Water	18.9	42.4 bc	71.7 bc	98.8 bc	124.3 b	141.4 bc	166.4 bc	205.3 bc	288.13 b	324.44 b
Clorox	17.1	51.8 b	78.8 b	112.48 b	139.8 b	161.8 b	175.2 b	209.1 b	289.81 b	336.69 b
Common salt	34.1	113.8 a	140.8 a	169.1 a	195.6 a	226.3 a	238.7 a	272.9 a	382.94 a	427.69 a
Vinegar	14.2	30.1 c	46.8 c	67.7 d	88.3 c	107.6 d	129.8 c	160.3 d	248.31 b	276.50 c
Pr≥F	ns	**	**	**	**	**	**	**	**	**
LSD	19.746	16.002	25.086	23.379	24.983	31.291	37.046	36.121	49.705	45.016
CV	91.22	28.28	31.34	21.45	18.82	20.04	21.06	17.27	16.55	13.08

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 3. Decay % of tomato as affected by storage temperatures and different sanitizers in rainy season.

Treatment	Decay fruit %									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30 DAS
Ambient	1.6	10.5	19.4	25.3	30.8	35.7	39.6	41.6	61.3	68.7
Cold	0.0	2.0	2.9	5.3	7.7	10.1	16.5	25.4	59.8	68.2
Control	0.0	1.5	7.3	10.2	13.1	18.6	24.8	33.6	62.4	88.0
Water	1.0	8.5	12.6	15.5	21.0	23.9	26.9	32.4	49.3	75.1
Clorox	1.6	12.5	19.3	25.6	28.2	31.2	36.3	42.0	65.6	-
Common salt	1.0	6.7	11.9	16.2	21.9	27.2	31.4	35.8	64.5	90.3
Vinegar	0.5	2.0	4.6	9.1	12.2	13.8	20.8	23.8	60.8	76.1

Appendix 4. Decay % of tomato as affected by storage temperatures and different sanitizers in winter season.

Treatment	Decay fruit %									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30 DAS
Ambient	0.2	4.6	6.2	9.9	11.6	13.1	14.9	19.8	26.3	34.4
Cold	0.0	0.2	0.7	1.4	1.4	2.2	2.4	4.2	9.8	13.2
Control	0.5	0.5	0.5	2.0	3.1	4.1	5.2	7.3	13.0	19.5
Water	0.0	0.5	2.2	4.4	4.4	4.4	7.1	12.0	19.6	25.5
Clorox	0.0	2.1	2.7	5.8	6. 9	8.5	8.5	14.4	19.2	23.4
Common salt	0.0	8.3	10.7	14.3	15.5	17.8	18.4	20.1	30.1	35.5
Vinegar	0.0	0.5	1.0	1.6	2.6	3.7	4.2	6.3	8.3	15.1

Appendix 5. Color of tomato as affected by storage temperatures and different sanitizers in rainy season.

Treatment	Color									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30 DAS
Ambient	4.9	5.1	5.3 a	5.7 a	6.0 a	6.0	6.0	6.0	6.0	6.0
Cold	4.9	5.0	5.1 a	5.5 b	5.8 b	6.0	6.0	6.0	6.0	6.0
Pr≥F	ns	ns	*	*	**	ns				
LSD	0.049	0.059	0.147	0.147	0.077	0.017				
Control	5.0	5.1	5.5 a	5.8 a	5.9 ab	6.0	6.0	6.0	6.0	6.0
Water	5.0	5.0	5.2 b	5.4 b	5.9 b	6.0	6.0	6.0	6.0	6.0
Clorox	5.0	5.1	5.3 ab	5.7 a	6.0 a	6.0	6.0	6.0	6.0	-
Common salt	4.9	5.0	5.1 b	5.4 b	5.7 c	6.0	6.0	6.0	6.0	6.0
Vinegar	5.0	5.0	5.2 b	5.6 ab	5.9 ab	6.0	6.0	6.0	6.0	6.0
Pr≥F	ns	ns	*	*	**	ns				
LSD	0.078	0.093	0.232	0.233	0.121	0.028				
CV	1.53	1.81	4.32	4.06	2.00	0.45				

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 6. Color of tomato as affected by storage temperatures and different sanitizers in winter season.

Treatment	Color									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30 DAS
Ambient	5.6 a	5.66 a	5.8 a	6.0 a	6.0	6.0	6.0	6.0	6.0	6.0
Cold	5.5 b	5.5 b	5.6 b	5.7 b	6.0	6.0	6.0	6.0	6.0	6.0
Pr≥F	**	**	**	**						
LSD	0.075	0.091	0.090	0.054						
Control	5.6 a	5.6 a	5.9 a	5.9	6.0	6.0	6.0	6.0	6.0	6.0
Water	5.5 ab	5.6 a	5.7 ab	5.8	6.0	6.0	6.0	6.0	6.0	6.0
Clorox	5.5 bc	5.6 a	5.8 ab	5.9	6.0	6.0	6.0	6.0	6.0	6.0
Common salt	5.4 cd	5.5 ab	5.6 bc	5.8	6.0	6.0	6.0	6.0	6.0	6.0
Vinegar	5.4 d	5.4 b	5.6 c	5.8	6.0	6.0	6.0	6.0	6.0	6.0
Pr≥F	0.119	0.144	0.142	0.085						
LSD	**	*	*	ns						
CV	2.12	2.52	2.43	1.42						

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 7. Firmness of tomato as affected by storage temperatures and different sanitizers in rainy season.

Treatment	Firmness									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30 DAS
Ambient	3.0	2.9 b	2.7 b	2.5 b	2.4 b	2.2 b	2.1 b	2.0 b	1.0	1.0
Cold	3.0	3.0 a	3.0 a	2.9 a	2.8 a	2.6 a	2.3 a	2.1 a	1.0	1.0
Pr≥F	ns	**	**	**	**	**	**	*	ns	ns
LSD		0.059	0.126	0.158	0.122	0.137	0.129	0.166		
Control	3.0	3.0 a	2.9 a	2.8 a	2.7 a	2.5	2.2 b	1.9 ab	1.0	1.0
Water	3.0	3.0 a	2.9 a	2.8 a	2.7 a	2.5	2.2 ab	2.1 ab	1.0	1.0
Clorox	3.0	2.9 b	2.7 b	2.4 b	2.3 b	2.2	2.1 b	1.9 b	1.0	-
Common salt	3.0	2.9 ab	2.8 ab	2.7 a	2.6 a	2.4	2.2 ab	2.2 a	1.0	1.0
Vinegar	3.0	2.9 ab	2.8 b	2.7 a	2.6 a	2.4	2.4 a	2.2 a	1.0	1.0
Pr≥F	ns	*	*	**	**	ns	*	*	ns	ns
LSD		0.093	0.199	0.250	0.192	0.216	0.203	0.262		
CV		3.10	6.90	9.12	7.32	8.80	8.93	12.38		

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 8. Firmness of tomato as affected by storage temperatures and different sanitizers in winter season.

Treatment	Firmness									
	3DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	21 DAS	24 DAS	27 DAS	30 DAS
Ambient	3.0	2.9 b	2.7 b	2.6 b	2.5 b	2.4 b	2.2 b	2.2 b	1.9 b	1.8 b
Cold	3.0	3.0 a	3.0 a	3.0 a	2.9 a	2.8 a	2.6 a	2.5 a	2.3 a	2.0 a
Pr≥F	ns	**	**	**	**	**	**	**	**	**
LSD		0.065	0.069	0.123	0.108	0.102	0.123	0.151	0.145	0.142
Control	3.0	3.0 a	2.9 ab	2.8 ab	2.7 ab	2.5 b	2.2 c	2.2 b	1.9 b	1.7 b
Water	3.0	3.0 a	2.9 ab	2.9 ab	2.8 a	2.6 ab	2.4 b	2.4 ab	2.1 b	1.9 ab
Clorox	3.0	2.9 a	2.9 ab	2.8 ab	2.7 ab	2.5 b	2.4 bc	2.2 b	2.0 b	1.8 b
Common salt	3.0	2.8 b	2.7 b	2.7 b	2.5 b	2.4 b	2.4 bc	2.2 b	2.1 b	1.8 b
Vinegar	3.0	3.0 a	2.9 a	2.9 a	2.8 a	2.7 a	2.7 a	2.5 a	2.4 a	2.1 a
Pr≥F	ns	**	**	ns	*	**	**	*	ns	ns
LSD		0.102	0.109	0.194	0.171	0.162	0.194	0.239	0.229	0.225
CV		3.41	3.74	6.77	6.21	6.20	7.88	10.06	10.41	11.63

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns,* and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 9. Shelf-life of tomato as affected by storage temperatures and different sanitizers in rainy season.

Treatment	Shelf-life
Ambient	20 b
Cold	24 a
Pr≥F	**
LSD	1.0100
Control	22 a
Water	25 a
Clorox	17 b
Common salt	23 a
Vinegar	24 a
Pr≥F	**
LSD	1.6105
CV	20.55

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 10. Shelf-life of tomato as affected by storage temperatures and different sanitizers in winter season.

Treatment	Shelf-life
Ambient	24 b
Cold	30 a
Pr≥F	**
LSD	2.78
Control	25
Water	27
Clorox	27
Common salt	24
Vinegar	30
Pr≥F	ns
LSD	4.3917
CV	16.08

Means followed by the same letters within a column are not significantly different based on LSD at 5% level ns, and ** indicate F test non-significance, significance at 0.05 and 0.01 probability level respectively. DAS – Days after storage

Appendix 11. Temperature and relative humidity recorded during storage of tomato under ambient condition in rainy season.

Storage date	Temperature (℃)		Relative Humidity (%)	
	Minimum	Maximum	Minimum	Maximum
6.8.17	22.1	36	11	75
7.8.17	22.1	36	11	75
8.8.17	27.1	38	21	75
9.8.17	22.1	36	11	75
10.8.17	27.1	38	19	75
11.8.17	29.7	38	20	75
12.8.17	22.1	36	11	75
13.8.17	22.1	36	11	75
14.8.17	22.1	36	11	75
15.8.17	20.1	34	10	75
16.8.17	22.1	36	11	75
17.8.17	22.1	36	11	75
18.8.17	22.1	36	11	75
19.8.17	22.1	36	11	75
20.8.17	22.1	36	11	75
21.8.17	20.1	34	10	75
22.8.17	22.1	36	11	75
23.8.17	22.1	36	11	75
24.8.17	26.6	38	18	75
25.8.17	22.1	36	11	75
26.8.17	22.1	36	11	75
27.8.17	22.1	38	11	75
28.8.17	22.1	36	11	75
29.8.17	27.4	38	17	75
30.8.17	22.1	36	11	75
1.9.17	22.1	36	11	75
2.9.17	30.1	38	13	75

Appendix 12 Temperature and relative humidity recorded during storage of tomato under ambient condition in winter season.

Storage date	Temperature (℃)		Relative Humidity (%)	
	Minimum	Maximum	Minimum	Maximum
10.1.18	21	29	15	63
11.1.18	21	29	15	55
12.1.18	21	29	15	65
13.1.18	21	30	15	70
14.1.18	21	29.5	15	68
15.1.18	19	28	20	66
16.1.18	19	28	23	69
17.1.18	23	31	22	72
18.1.18	19	26	24	55
19.1.18	19	27	25	55
20.1.18	17	24	22	68
21.1.18	16	26	22	69
22.1.18	18.5	27	25	57
23.1.18	17	27	26	71
24.1.18	19	28	15	65
25.1.18	19	28	15	65
26.1.18	19	28	15	65
27.1.18	19	27	15	65
28.1.18	20	30	15	55
29.1.18	20	30	15	55
30.1.18	20	30	15	55
31.1.18	20	30	15	55
1.2.18	19	29	15	65
2.2.18	19.5	29	15	65
3.2.18	19	28	15	65
4.2.18	19	28	15	65
5.2.18	19	28	15	

Tomato

Soaked in sanitizer

Allowed in air dry for 15 mins

Cold storage at 13℃

Storage under ambient condition

Plate 4 Experimental Procedure